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ABACÁ AND ITS IMPROVEMENT [1]

D. L. UMALI and J. L. BREWBAKER

Abacá, the fiber of *Musa textilis* Née, is known in international commerce as Manila hemp. This product provides the primary income of one out of every seven Filipinos and brings over two million pesos in federal taxes annually.

Abacá production has been set back seriously as a result of the war and subsequent mosaic disease. Competition of Philippine fiber with abacá from Central American countries as well as with synthetic fibers has increased greatly in the last ten years.

To maintain the abacá industry at a prominent place in Philippine economy, improvements in the plant and its culture and processing must be made. Foremost among these is to establish disease resistance by breeding.

An attempt is made in the following paper to give a comprehensive review of investigations as they relate to the improvement of this important crop plant.

USES AND WORLD PRODUCTION

The commercial name of abacá is a compounded misnomer, for Manila hemp is neither produced in Manila nor is it hemp. Apparently the name was acquired because abacá, a leaf fiber, was exported through the port of Manila and used as a substitute for the stem fiber of true hemp (*Cannabis sativa*).

Abacá, the strongest commercial cordage fiber, is thrice as strong as cotton, twice as strong as sisal or henequen, and stronger than true hemp. Longitudinally, its strength is outstanding although it is relatively weak transversely (Spencer, 1953). Abacá is the world's best fiber for rope making, especially for marine cordage which requires resistance to salt water decomposition. Its superiority for marine use was first demonstrated by American Navy Lieutenant John White soon after the Napoleonic Wars (1796-1815) when the supply of Russian hemp was cut off, but it was during the Crimean

[1] General Contribution No. 877. Prepared in the Division of Plant Breeding, Department of Agronomy.

War (1854-1856) when the U.S. was again deprived of Russian hemp that abacá became the premier cordage fiber (Balmaceda and Bartolome, 1935).

The earliest known use of abacá fiber in Oriental countries was in the weaving of fishing nets and clothing. In cloth making, the finer fibers of the inner sheaths of the stalk are pounded to soften them before use. The cloth woven from plain abacá fiber is known as "sinamay," and the colored cloth woven from abacá fibers mixed with colored cotton or silk threads (abacá fibers do not dye easily) is called "jusi."

Most of the Philippine abacá is exported. After sugar and copra, it is the most important export crop of the country. A large volume of abacá is used in the Philippines for ropes, strings, fishing nets, native clothing, table cloths, belts, slippers, mats, rugs, hats, purses, and other domestic handicraft for export. In Japan, abacá is used in the manfacture of heavy paper or boards which serve as movable partitions. For the last decades, the United States and various European countries have utilized old ropes, waste, and lower grades of abacá fiber in the manufacture of heavy paper bags for flour, cement, fertilizer, lime, and other products.

Before World War II, the Philippines supplied practically the world's entire abacá requirement. In 1912, the production was 172,000 tons (Saleeby, 1913), and from 1934 to 1939, the average was 173, 400 tons (Cruz, 1947). Abacá production dropped to 114,600 tons in 1952 (Cruz, 1953a). The Philippine monopoly on abacá has been broken, and year after year, abacá meets more competition, not only from plant fibers produced from other countries, but also from synthetic fibers (Kent, 1954) and metallic wires.

The world acreage grown to abacá is about 290,000 ha. of which approximately 275,120 ha. in 1952 were in the Philippines. In Central America, the areas planted to abacá in 1949 were Costa Rica, 4210 ha; Guatemala, 2186 ha.; Honduras, 2020 ha.; and Panama, 2511 hectares. As of 1951, British North Borneo had 1042 ha. and Indonesia, 1500 hectares.

In the Philippines, the over-all average production is only 450 kg. per hectare. In Southeastern Mindanao, however, where large plantations use better cultural methods and efficient decorticating machines in reclaiming fibers, the average production is 1,540 kg. per hectare which is comparable to the average production of 1,480

kg. per hectare in some South American countries where plantings are on a regular plantation basis (Spencer, 1953). The Philippines leads in the production of this crop because of its favorable climate and soil conditions. Although the Central American countries, British North Borneo, Indonesia, and Malaya are now producing abacá on a large commercial scale, 87 per cent of the world's production of about 150,000 tons in 1953 still came from the Philippines.

Abacá production in the Philippines has not reached its prewar level largely because of mosaic disease which has become epidemic due to the chaotic production conditions and bad cultural practices which prevailed after World War II (Johnson, 1953). Agati (1953) reported that 62,823 out of 84,238 hectares of abacá in Mindanao and Sulu showed varying degrees of infection in 1951. Mosaic is a serious threat to the industry which gives the country an annual income of ₱99,000,000 and a corresponding tax revenue of ₱2,000,000 and upon which about three million people are dependent for their livelihood (Merino, 1953; Cruz, 1953b). Several control measures such as careful elimination of diseased clones and insect vectors have been recommended, but apparently the best control appears to be the breeding of mosaic-resistant lines. Two other serious diseases of abacá to which resistance should also be obtained are bunchy-top and wilt.

There are at present several mosaic-free abacá-growing countries which in the future may successfully compete with the Philippines. For the latter to maintain its place in the world market, it is essential to lower the production cost compared to that in the competing countries. One means of reducing production cost is to grow improved varieties that give a high yield of good quality fiber. Such variety improvement can only be achieved through breeding.

ORIGIN AND DISTRIBUTION

There is apparently little doubt that *M. textilis* is indigenous to the Philippines. The presence of related species of the *Australimusa* section in neighboring islands of the Philippines definitely makes this area a center of great diversity of the genus. Chandraratna (1953) is inclined to consider the Assam-Malay Peninsula as the most probable center of origin and diversity of the genus *Musa*. He further regards it as possible that *Australimusa* forms originated in the periphery of this area, later becoming extinct at the place of origin while the species migrated further east to the East Indies.

Preliminary studies of abacá in the Bicol region (Brewbaker, Gorrez, and Umali, 1956) failed to reveal any wild forms of *M. textilis* but a thorough search in this area for such forms would be of great value. Types referred to as "wild abacá" have proven to be plants (generally called amoquid) grown from seed in the mountains. These forms were found to be hybrids of *M. textilis* and *M. balbisiana* (canton, minay) and of *M. textilis* and *M. banksii* (alinsanay).

As a wild plant endemic in the Philippines, abacá was domesticated by Filipinos. Many fiber plants were probably tried by early Filipinos, and some of these, like pacol (*Musa balbisiana*) and canton, a suspected hybrid of *M. balbisiana* and *M. textilis*, have some uses today. When abacá was first domesticated and when it was first raised profitably on a plantation scale are not known. Its cultivation and its use in cloth making were already developed when the Spaniards came to the islands in 1521. Dampier, an English navigator, reported in 1697 that a plantain, supposedly abacá, was being grown in Mindanao for its fiber (Robinson and Johnson, 1953).

The Bicol region (Southern Luzon) seems to be the place where abacá was first domesticated because the greatest number of abacá varieties and semi-wild types are found there. Lanuza (1953) reported that 70 varieties were being grown in that area. Canton and minay, probable hybrids of abacá and *M. balbisiana*, originated in the province of Albay (Brewbaker, Gorrez, and Umali, 1956). Alinsanay, a probable hybrid of abacá and *M. banksii* (saguing maching), is found in the mountains of Camarines (Brewbaker and Gorrez, 1956). Furthermore, the abacá industry was more highly developed in the Bicol region in the 19th century than in any other region. In 1901 abacá production in the Bicol region was 66 per cent of the total abacá production of the islands as compared with 25 per cent in the Samar-Leyte region, 6 per cent in Mindanao, and 3 per cent in the other districts (Nesom, 1908). To help prove the assumption of Bicol origin, taxonomic and cytogenetic studies of the different types and wild forms of abacá existing in the three regions should be made.

From the Philippines, abacá spread to Borneo and the East Indies. At the start of the 19th century, several countries attempted to grow this crop. Copeland (1911) reported that by 1811, India had tried to grow abacá from seeds and that since the plants were of poor fiber quality, repeated plantings were made. At about the

same time, attempts were made to grow abacá in Ceylon, the Andaman Islands, Bengal, Hawaii, Sumatra, Java, Celebes, New Guinea, the Solomon Islands, the Fiji Islands, Jamaica, and Trinidad in the West Indies (Spencer, 1953). Although the plants thrived in these places, fiber production was very poor because the plantings were made from seeds which failed to breed true. Furthermore, the plants might not have performed well because the people growing them did not know much about the soil, climatic, and cultural requirement of abacá. In 1901-1903 the trial plantings in Hawaii, Florida, Puerto Rico, and Cuba failed. In 1908, abacá was introduced into the Dominican Republic from planting materials obtained from Thailand (Corney, N. S., J. R. Furlong, and R. H. Kirby, 1947).

The early attempts in 1924 and 1925 to introduce abacá into the western world were failures (Robinson and Johnson, 1953). According to Edwards (1946), the first successful shipment of abacá planting materials from the Philippines to America was made possible by him through the cooperation of two leading American producers. The large-scale shipment of abacá materials to the western hemisphere where the production might be a great threat to the Philippine monopoly of the fiber supply, alarmed the Filipinos, and in 1925 the Philippine Legislature passed a law prohibiting the exportation of abacá seeds or rootstocks to foreign countries. From the last shipment of corms from six varieties in 1925, 500 plants were grown in a nursery near Almirante, Panama. This nursery was expanded to 50 acres in 1928, 1000 acres in 1937, and 2,000 acres in 1939. During World War II the planting was further expanded, and by 1943, 11,472 acres had been planted in Costa Rica, 5,716 acres in Guatemala, 5,012 acres in Honduras, and 4,145 acres in Panama (Edwards, 1944). All the Central American plantations are managed by the United Fruit Co. which is under contract with the U.S. government. The Brazilians and the Ecuadoreans after years of experimentation found regions in their countries where abacá could be grown successfully. In 1953 the U.S. government had an agreement with Ecuador to plant 7,000-8,000 acres to abacá. In 1949, planting materials were sent by U.S.D.A. to Bolivia, Peru, Nicaragua, and El Salvador. Abacá is now widely distributed in the Western hemisphere.

CULTURAL HABITAT

According to Rojales (1921), Espino and Esguerra (1923), Aldaba (1922), and Cruz (1947), the primary environmental requirements for profitable abacá culture are the following:

Uniformly distributed rainfall. Abacá thrives best where the rainfall is uniformly distributed and the dry season is not prolonged. The annual rainfall in Philippine abacá regions ranges from 2 meters (Cotabato) to 4.5 meters (Samar). Six-week rainless periods may decrease the quality and quantity of the fiber of some varieties. Low humidity and long dry periods may even kill the plant. The uniform distribution of rainfall in the Davao area provides almost ideal conditions for abacá growth.

Good rich soil. Sandy to sandy-loam soils of good fertility and good drainage appear to be best for abacá. Abacá can not stand a high water table nor will it thrive sucecssfully in a soil containing a hard pan or shallower than 3/4 of a meter. Since it requires long-term culture, sometimes 50 years without replanting, it also requires a constantly fertile soil. Fertilization normally has not been practised in the Philippines, but it appears to merit consideration for older plantings. Micro-element deficiencies may be the cause of the deterioration of some old plantings, but little research has been conducted on this problem.

High annual temperatures and humidity. An average annual temperature of at least 27.0°C is a requirement. Abacá may be cultivated at elevations as high as 1,200 meters in the Philippines; above this altitude, the temperature may be a limiting factor in culture. A humidity range of 78 to 88 per cent is conducive to good abacá growth.

Freedom from strong winds or typhoons. Strong winds tear the leaves and often uproot the stalks. A severe typhoon may set back fiber production for more than a year. From this standpoint, Southern Mindanao, which is seldom visited by typhoons, is an ideal region for abacá culture. Luzon, which is in the typhoon belt is especially unsuitable for growing abacá.

Full sunshine and free circulation of air. Plants in old plantations which were exposed to sun and free air circulation yielded almost double the amount of fiber obtained from plants grown under heavy shade and with little wind circulation (Espino and Reyes, 1923). However, sparse shading in relatively new plantings enhances fiber yields in the Bicol area, where the shade serves to help control grass and other weed growth and also minimizes the effect of drought and typhoons. In older plantations a full-shade tree cover may be unnecessary and even detrimental to yield.

OUTSTANDING VARIETIES

According to Espino and Esguerra (1923), there are about 100 known varieties of abacá in the archipelago. About 70 varieties are under cultivation in the Bicol region, 20 in Mindanao, and 12 in Leyte and Samar (Lanuza, 1953). However, only about 20 varieties are of recognized commercial importance.

The known varieties of abacá differ considerably in their morphological and agronomic characters, such as size, shape, and color of the stalk; size, shape, and texture of the leaves and the manner in which the leaves hang on the stalk; color and shape of the flower bud; stooling habit of the plant, rapidity of development and length of life of the plant; degree of drought and wind resistance and of adaptability to various soil conditions; resistance to disease; and the quantity and quality of the fiber and the relative ease or difficulty with which it is stripped (Robinson and Johnson, 1953). Espino and Esguerra (1923) and Espino and Reyes (1923) found that the texture, length, thickness of cell walls, and tensile strength of the fibers of twelve varieties differed markedly. Espino and Esguerra (1923) also observed that none of the 46 varieties they studied possessed all the desirable qualities of stalk, stool, and plant. Bulao and Libuton were considered to have the maximum number of desirable agronomic characters. These characters include the following (Espino and Esguerra, 1923; Mendiola, 1926; Lanuza, 1953): high yield of fiber with high tensile strength, fiber of fine texture, white and lustrous, good stooling capacity, resistance to drought and strong winds, extensive and deep root system, ease in "tuxi" and stripping, long period of production, fast growth, and early maturity. To these may be added the character of disease resistance which so far none of the commercial varieties has exhibited with respect to mosaic, bunchy-top, or wilt—the major abacá diseases. A comprehensive survey of other abacá varieties for resistance to mosaic should be made.

The three standard varieties most commonly grown in Mindanao are Tangongon, Maguindanao, and Bungolanon. The varieties Tangongon and Bungolanon are widely established in Malaya (Marsh, 1947), where fiber quality compares favorably with that of commercial Philippine abacá grades. The last two are also the outstanding varieties in Central America (Berkeley *et al.*, 1949). Each variety has good qualities not found in the other two, but although all three are being grown profitably, not one can be classified as an ideal variety. A brief description of the three varieties follows:

Tangongon. This variety is large, vigorous, and the hardiest of the three. It grows well in heavy clay soils and is comparatively resistant to drought under Mindanao conditions. Its fiber is strong and heavy, but it is coarse, slightly colored, and hard to strip. Tangongon does not stool as well as the other varieties and hills tend to "run out." The large heavy stalks are frequently blown down because the rootstocks often push through the soil surface.

Maguindanao, which has large stalks closely approaching those of Tangongon are easily stripped. It will thrive well only in sandy loam to light clay loam soil. Because of its scanty root system, Maguindanao is sensitive to dry weather conditions and its stalks lodge easily. It is therefore of little value in the typhoon-swept Bicol and Leyte regions. It yields less than either Tangongon or Bungolanon.

Bungolanon is an earlier maturing variety than either Tangongon or Maguindanao. Because of its early maturity, there is less cultivation expense and financial returns are also realized early. It grows on a wider range of soil fertility and is more resistant to drought than Maguindanao. Because of its good root system, it does not lodge easily. Usually there are less weeds in a Bungolanon field because being a heavy stooler, it produces 30-60 stools which quickly shade the space between the rows. Bungolanon has one serious defect; its yield declines after five or six years, unlike Maguindanao which is productive for as long as fifteen years. The fiber yield is good, approaching that of Maguindanao and is more equally stripped than Tangongon. Although the fibers are not as long as those of the other varieties, they are white, fine and strong.

In the Samar-Leyte region, the three most important commercial varieties now being grown are Inusa, Linawaan, and Mininonga.

Inusa is hardy and resistant to drought and strong winds. It thrives well in medium fertile soil. However, it stools poorly, and its fiber is coarse and hard to strip.

Linawaan thrives well in rich soil. Its fiber is hard to strip but it is white, lustrous, and finer than Inusa. Because it is deep-rooted, Linawaan is resistant to strong winds and drought. It is a prolific producer of well-set stools.

Mininonga has more desirable agronomic characters than either Inusa or Linawaan. Mininonga has a finer and stronger fiber which is easy to strip. It would be an ideal variety for the Leyte-Samar region if it does not need fertile soil to perform well.

Of the many varieties grown in the Bicol region in Southern Luzon, the standard varieties are Samina, Lausigon, and Itom. None of these can be called "typhoon-resistant" although they are perhaps shorter-stemmed and more firmly rooted than the average abacá variety.

Samina needs fertile soil. Its strong roots make it a desirable variety in the Bicol region. Although it does not produce as much fiber as Maguindanao, the fiber is fine, white, of good tensile strength, and is very easy to strip. Its stooling capacity is only fair, yet plantations of this variety remain productive for many years.

Itom, like Samina has a good root system, but unlike Samina, it stools freely and is productive even in medium fertile soil. Its fibers are fine, white, and strong. This variety maintains its productivity for 12 years or more.

Lausigon is a hardy variety under Bicol growing conditions. It does not lodge easily and it can stand drought, but its fiber is coarse and hard to strip.

The statistics compiled by Professor Pedro A. David of the U.P. College of Agriculture show that for the last decade Tangongon has been the most widely cultivated standard variety (28,619 ha.). The other three ranking standard varieties, according to hectarage are Bungolanon (19,984 ha.), Itom (13,460 ha.), and Maguindanao (7,114 ha.). Maguindanao, with an average hectare-yield of about 1,108 kilos, is the most productive. The other high-yielding varieties are Tangongon (936 kg.), Layahon (936 kg.), and Bungolanon (651 kg.).

Not one of this group of common varieties under cultivation in the Philippines is ideal or perfect. Many other varieties are grown in the islands, but most of them have not been critically evaluated in replicated yield trials. The absence of comparative regional tests of leading varieties makes it difficult to estimate the range of their adaptability. According to Lanuza (1953), the Mindanao varieties (Maguindanao, Tangongon and Bungolanon) and those of the Leyte-Samar area (Mininonga, Layahon and Inusa) did not perform as well as the native varieties, Samina, Itom, and Lausigon in the Bicol region. Yet such varieties as Maguindanao and Bungolanon have proved to be well adapted to Costa Rica, Honduras, Panama, and Guatemala although yield and strength of fiber varied significantly between the stations sampled (Berkeley *et al.*, 1949). It is anticipated that different varietal recommendations will

be made for the Bicol-Visayan and for the Davao regions because of the rather great environmental differences between these regions.

GENETICS

Very little information is available on the genetics of abacá. Abacá varieties are commonly propagated asexually from clonal suckers. Attempts to establish plantings from seed have been largely unsuccessful because of the segregation of undesirable off-types. Variability in families derived from inter-varietal and from interspecies hybrids confirms alike the view that each of the varieties (clones) is highly heterozygous. Chlorophyll and dwarf mutants are conspicuous among the seedlings, and a wide range in the vigor, number and length of roots, height, stalk diameter, leaf sheath and petiole color, leaf sizes, stooling capacity, and fiber content have been observed among the seedgrown progeny (Mendiola, 1926). Progenies of varietal hybrids at the Guinobatan Abacá Experiment Station, Albay, show a similar range of variability to those reported by Mendiola.

From comparisons between pacol-abacá hybrids and their parents, the following dominance relationships have been inferred: mosaic resistance dominant over susceptibility, presence of waxy bloom dominant over absence, presence of coloration in leaves dominant over absence. Further study of these hybrids and subsequent backcross generation is necessary to determine the hereditary basis for these and other characters.

BREEDING METHODS

To coordinate abacá research in the Philippines, the Cooperative Abaca Improvement Program of the U.P. College of Agriculture, Bureau of Plant Industry, and Bureau of Agricultural Extension was initiated in March, 1954. Previous research in abacá selection, evaluation and hybridization has been rather limited. Therefore, the breeding methods outlined here are based as much on experience with similar crops as on results of experiments with the abacá plant.

Abacá is normally propagated vegetatively; hence the breeder has a one-plant goal, i.e., to find the plant which has the most desirable combinations of characters. In the Philippines, the present need is to obtain a mosaic-resistant clone. This is particularly true in Mindanao, where mosaic threatens to wipe out the abacá industry (Kent, 1954). Resistance to this disease does not appear to occur

within the species *M. textilis* although no thorough surveys have been made to substantiate this theory. With this immediate objective in mind, four projects under the Cooperative Abacá Improvement Program have been undertaken. These are varietal classification and evaluation, observational and disease nurseries, clonal selections and progeny trials, and intra- and inter-specific hybridization.

Varietal classification and evaluation. The first step in breeding any crop is systematic survey of available material. Before World War II, great strides were made in the study of abacá varieties in the Philippines but most of the information was lost when the experiment stations, government museums, libraries, and herbaria were burned and destroyed. The original comprehensive study of Vista (1920) was lost at this time, although reviews of his early classifications of abacá still exist. A standard procedure for classifying varieties following Vista was outlined recently by Lanuza and Umali (unpublished) and is being applied to all Philippine abacá strains. Primary emphasis is placed on important agronomic characters, (stooling capacity, height, and robustness) and on those characters of the inflorescence upon which the environmental influence is slight (length and width of tepals, number of flowers per hand).

Evaluation of Philippine abacá varieties has been made largely on a regional basis. Replicated varietal trials include those at (a) Guinobatan, Albay: 11 varieties in 12 replications of 16-hill plots, established in 1950; (b) Bago Oshiro, Davao: 45 varieties in 4 replications of 8-hill plots, established in 1954; and (c) Economic Garden, Los Baños, Laguna: 32 varieties from all abacá regions in 4 replications with 6-hill plots, established in 1954-55.

The outstanding varieties grown in each of the three major abacá regions differ according to the growing conditions of their respective regions. Resistance to lodging and drought is important in the Leyte-Samar and the Bicol regions where typhoons and dry seasons are often severe. The absence of strong winds, a uniform distribution of the yearly rainfall, and severe damage from mosaic in the Davao region must be considered in choosing varieties for this area. There is need for a critical appraisal in all regions of at least the outstanding varieties considered previously in this paper.

The field designs of current abacá yield trials vary considerably, and the relative efficiency of these designs has not been determined. The use of single-plot replications appears to merit study as it may result in appreciable saving of costs without loss of ac-

curacy. The use of 10-15 replications of single-plant plots with 3 to 5 years' data may be recommended in the light of results from similar trials with coffee (Krug and Carvalho, 1952).

Observational and disease nurseries. The largest Philippine collection of abacá varieties is at Guinobatan Abacá Station, Albay. It includes over 75 clones obtained largely from the provinces of Albay, Sorsogon, Camarines Sur, and Camarines Norte. This region is the most probable center of origin of abacá and is an ideal place for a comprehensive varietal collection. The present nursery consists of 12 hills of each line spaced about 3 meters apart and grown under partial shade.

Musa species collections are of considerable importance to the abacá breeder, since it appears that resistance to mosaic, wilt, and bunchy-top may not be available within the species *M. textilis.* A small collection at the U.P. College of Agriculture includes *M. ornata, M. balbisiana, M. banksii, M. textilis* and cultivated edible bananas of *M. paradisiaca* and *sapientum.* Also in this collection are the suspected hybrids of two species, canton, minay, and alinsanay. The most comprehensive collection of species in the world is at the Imperial College of Tropical Agriculture in Trinidad, B.W.I., ironically situated half-way around the world from the center of origin and diversity of most *Musa* species.

All the collections at the U.P. College of Agriculture are being tested for resistance to mosaic, bunchy-top, and wilt. Field tests for mosaic resistance are being conducted at the Davao Abacá Experiment Station. Pathological studies of the abacá mosaic virus were reviewed in detail by Kent (1954).

Clonal selection and progeny trial. Since abacá is highly heterozygous, new and better varieties may possibly be produced from seed-grown progenies (Mendiola, 1926). The first step would be to select well-adapted and high-yielding varieties in a region and then to harvest bunches of fruits from selected hills of each variety. The seeds from these bunches can be considered as selfed if the plantation is planted to a single variety. Immediately after the seeds are removed from the fruit and washed, they should be sown 1-2 cm. deep in seedboxes exposed to partial sunlight (Torres and Lanuza, 1954). The seedlings are then transplanted in nursery rows, and only the fast-growing and vigorous seedlings with good root systems

are transplanted in the field, with the parental variety interplanted as checks.

The possible appearance of clonal variants or mutants in abacá single-clone plantings merits consideration in abacá breeding. This appears to be especially true with respect to disease-resistant hills in established abacá plantations, as in the mosaic-destroyed plantings in Davao.

Hybridization. In its simplest terms, the objective in abacá breeding is maximum yield of fiber per hectare at minimum cost. To plant breeders, the objective implies better quality, higer yield, and more economical production of fiber. In the Philippines at present, hybridization for the production of high-yielding and mosaic-resistant abacá is of primary importance.

1. *Inter-varietal crosses—*

To create the gene combination desired, the breeder must first choose carefully the parental stocks. In varietal hybridization, two standard varieties whose desirable characters are supplementary may be crossed to produce progenies bearing the desirable qualities of both parents. For instance, for the growing conditions in Mindanao, Tangongon, a hardy, drought-resistant variety which thrives over a wide range of soil fertility but which has poor stooling capacity and coarse fibers that are hard to strip, may be crossed with Maguindanao which produces more suckers and gives a fairly high yield of fine, soft, and white fiber, but which is selective in soil requirements and sensitive to dry weather conditions and strong winds.

If the desired progeny does not appear in the F_1, the hybrid may be selfed and the selections made in the F_2 segregating generations, or the F_1's may be backcrossed to one of the parents to recover fully the germ plasm of the more desirable parent. Another promising approach in the synthesis of new varieties is the selection of parents representing the greatest possible genetic diversity. Since vegetative propagation is used to multiply any desirable progeny of such a cross, the full benefit of heterosis may be maintained indefinitely. Favorable effects of genetic diversity may be derived by crossing two outstanding varieties from different regions. A promising study in the production of new combination would be the systematic crossing between the outstanding commercial varieties of the Bicol region, the Samar-Leyte area, and Mindanao.

The ultimate goal of the abacá breeder is to concentrate into a single clone all the existing genes that can contribute to higher yield under the prevailing environmental conditions. It may be assumed that a considerable portion of the genes affecting favorably the yield still remain scattered among many varieties or strains of abacá. To concentrate these genes in a superior clone for a given cultural environment requires the genetic exploration of a great number of widely diverse breeding materials. It is also possible that this exploration will yield little or no fruitful results and that the desired results may be achieved only after several generations of crossing and backcrossing.

The first attempt to cross commercial varieties of abacá was made in 1928 at the Guinobatan Abacá Experiment Station, but the hybrids produced were lost either because of plant damage by disease or abandonment of the project due to lack of funds. Just before the outbreak of World War II, Maguindanao and Putian were crossed and the hybrid progenies tested. According to Garrido (1953), the hybrids had longer and larger stalks and produced more suckers than either parent.

In 1951, hybridization of promising standard varieties was resumed at the Davao Abacá Experiment Station, the Guinobatan Abacá Experiment Station, and the Economic Garden. Promising hybrid clones which escaped mosaic infection were produced from the crosses made in Davao. More than 1,000 hybrid seedlings from crosses of 11 varieties are now being grown in nursery plots in the Economic Garden.

At the College of Agriculture the following inter-varietal hybrids were produced by Dr. P. A. David of the Department of Agronomy: Putian x Kinalabao, Putian x Jolo, and Maguindanao x Kinalabao. Old hills of these hybrids are still growing in nursery rows. It would be worthwhile to study their agronomic characters and performance.

2. *Inter-specific crosses—*

The emphasis on abacá improvement now is on breeding of mosaic-resistant strains. This virus disease, which is transmitted mainly by aphids, reduces the yield of the plant, especially when infection occurs during the early stages of growth. The fibers of diseased plants are short, discolored, and weak (Reyes, 1954; Kent, 1954).

All the standard varieties of abacá are reported susceptible to mosaic and so far all efforts to find a resistant strain of abacá have proved futile. The only promising sources of resistance are its near relatives, pacol (*M. balbisiana*) and canton, which are known to be not only resistant but also immune to mosaic and bunchy-top. Pacol and abacá were observed to be reciprocally compatible, but canton was considered useless as a parental stock because of its complete sterility (Umali and Valdez, 1949). In one case, seeds were obtained from the cross abacá x canton at the College; proof of hybridity of the seedlings has not yet been obtained.

From the crosses made since 1949, the College of Agriculture now has hybrids from seven abacá varieties crossed with pacol. To insure that the seedling progenies are true hybrids, the male abacá parents used should have dominant genetic markers which can be readily recognized in the hybrids. Where abacá is the female parent, the dominant marker is the waxy bloom of pacol on the nether surface of the leaf. All these hybrids failed to show symptoms of mosaic even after the third inoculation with the disease (Umali and Bernardo, 1956). Since they could not be made to serve as source of mosaic for abacá seedlings, these hybrids may be considered not merely tolerant but resistant or immune. They are now being grown under field conditions for subsequent backcrossing to at least two of the most outstanding varieties from each of the three abacá regions. Suckers from each hybrid will be sent to the Davao Abacá Experiment Station for inoculation with the virus, believed to be a more virulent strain, in that place.

At the Economic Garden and at the Davao Abacá Experiment Station, thousands of hybrid seedlings from the crosses between pacol and the varieties Tangongon, Maguindanao, and Bungolanon are being grown, and all have been reported resistant to mosaic.

Another problem is whether or not it is possible to produce resistant progenies by crossing two abacá clones. Resistance may be found in another form, possibly morphological which may require complementary action of two or more genes already present in different varieties of abacá. The systemic resistance of pacol appears to be a dominant factor, and if the parental abacá stocks do not show it, it is highly improbable that this particular type of resistance will appear in the progenies.

The other major abacá disease to which resistance is being bred into abacá is bunchy-top, the virus disease responsible for wiping

out the abacá industry in Cavite, Batangas, and Laguna in 1910-1920. This disease was reported from Sorsogon in 1935. All commercial varieties of abacá are equally susceptible to it. The virus is transmitted by aphids, *Pentalonia nigronervosa* Coq. The false stem of an infected plant does not increase in length, and the plant decreases in size until it finally dies in two years (Ocfemia, 1931). Bunchy-top, however, is less serious than mosaic because it is more or less self-eliminating. A plant infected with bunchy-top usually dies before it can propagate itself.

The same batch of pacol-abacá hybrids inoculated with mosaic were also inoculated with bunchy-top (Umali and Bernardo, 1956). After five months of mass inoculation, the hybrids showed signs of recovery, indicating that stunting was due to the plants being root-bound rather than diseased. Six successive inoculations from these plants to susceptible strains of abacá failed to reproduce bunchy-top, proving that the plants were not a source of the virus.

Wilt, *Fusarium cubense* EFS, the dreaded Panama disease of banana in Central America, is another abacá disease commonly found in Davao, especially in places with poor drainage. It causes rotting of rootstocks and stalks and yellowing of the leaves (Leoncio, 1930), and the infected plants die quickly. Umali, Ick, and Orillo (1956) found that pacol, abacá, pacol-abacá hybrids, and Latundan were susceptible to the disease and that canton, Bungolan, Gloria, and Lakatan were resistant. Minay, alinsanay, agotay, and saguing maching may be possible sources of wilt resistance.

PROBLEM OF TESTING FOR RESISTANCE

Because of the enormous number of hybrid seedlings in the care of plant breeders, it is important to establish procedures for handling economically a large number of seedlings and also to establish criteria for the intelligent selection of seedlings for commercial-scale tests. Testing the plants for resistance to either mosaic or bunchy-top is the bottle-neck in the present program. The biological test is very tedious and time-consuming; sometimes, tangible results can not be obtained even after six months. On the other hand, mechanical transmission of the virus has not proved successful so far. Currently, studies are being made at the College of Agriculture on the relationship between the biochemical properties of the sap and mosaic resistance so that a spot test for resistance may be developed for

mass-screening hybrid progenies. Resistant plants screened by this method will be finally tested for resistance in the greenhouse and in the field where they will be grown side by side with mosaicked plants.

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CLASSIFICATION OF PHILIPPINE MUSAE I. THE GENERA MUSA L. AND ENSETE HORAN [1]

JAMES L. BREWBAKER and DIOSCORO L. UMALI [2]

WITH ONE TEXT FIGURE

The Philippines and its neighboring islands of the East Indies constitute a broad center of diversification of *Musa* species. A wealth of variation is observable among Philippine Musae and is probably attributable in large part to the obligate cross-pollination of the banana plant and the common absence of absolute barriers to cross-fertilization within and among the species (Cheesman, 1947).

The biological variation of bananas—the term "banana" being used in the broad sense as applying to all *Musa* species—appears to be no less great in the Philippines than what is encompassed in the concept of a species. Nearly one hundred varietal names are applied to abacá (*Musa textilis* Née) alone, although many of these may be synonymous, having resulted from dialectic differences in spelling and pronunciation. Quisumbing (1919) reported that over 600 varieties of bananas were in the nurseries of the U.P. College of Agriculture in 1919. Ambiguities exist in the nomenclatural status of such forms as "pacol," "canton," "butuhan," and other well-known Filipino bananas. In this and accompanying papers the authors attempted to clarify these ambiguities and to set a foundation for the more intensive taxonomic and hybridization studies incident to the rapidly expanding cooperative abacá improvement program in the Philippines.

The systematics of the genus *Musa* has been revised and clarified recently in the comprehensive works of E. E. Cheesman. These have been liberally drawn from, as the nomenclatural basis for classification of Philippine forms. The classification of *Musa* species, as Cheesman (1947) points out, has been based largely on verbal descriptions and on drawings and photographs of material available to the systematist. The bananas cannot be easily identified and classi-

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[1] Central Experiment Station Contribution No. 1909.

[2] The writers acknowledge the assistance of Messrs. D. Baybay, A. Pasco, and E. Lanuza of the Bureau of Plant Industry in the collection and study of *Musa* species and strains.

fied in the absence of data and notes on living material. In the early part of the century, several field surveys were made in the Philippines (Teodoro, 1915; Copeland, 1927; Quisumbing & Elayda, 1926) and observational nursery plantings were started at the U.P. College of Agriculture in Laguna province, and at Alabang Station in Rizal province (Barrett, 1913). These nurseries have since been abandoned. It has been the decision of research workers in the cooperative abacá improvement program of the U.P. College of Agriculture and Bureau of Plant Industry to re-establish an observational *Musa* nursery at College, Laguna. In this connection, the present authors have had the opportunity to collect and study materials in various regions of Luzon and Mindanao. These studies are necessarily incomplete, since many of the regions of diversity in wild bananas are inaccessible at the present time. It is urged that intensive field surveys of the wild bananas be instituted at as early a date as possible, with particular emphasis on the search for sources of mosaic resistance, potentially transferrable to abacá (*Musa textilis*).

In Cheesman's classification the bananas are separated into two genera, *Ensete* Horan and *Musa* L.

THE GENUS ENSETE HORAN

The generic differentiation of *Musa* L. and *Ensete* Horan was established by Horaninow in 1862 (Prodromus Monographiae Scitamihearum) who used the specific epithet *Ensete edule* for an Abyssinian banana which has been more commonly referred to in the taxonomic literature as *Musa ensete* Gmel. Cheesman (1947) reproduced Horaninow's description and recognized the generic status of Ensete, transferring to it about 25 species previously included in the genus *Musa*. These comprise the entire subgenus Physocaulis (Baker, 1893) and several other species.

Distinguishing features of *Ensete* species include the absence of stooling and the monocarpic habit, enlarged basal portion of stems, common persistence of bracts, large (rarely less than 1 cm. in diameter), smooth and nearly globose seeds, and chromosome number of $n = 9$ in the seven species examined (Cheesman, 1947). The geographical distribution of *Ensete* species overlaps with that of *Musa*, although the former genus has shown its greatest development in Africa, from which no indigenous *Musa* species are known.

Two species of *Ensete* are found in the Philippines. *Ensete edule* Horan, the Abyssinian banana of Horaninow's early description, was

reported by Quisumbing (1919) and Teodoro (1915) as *Musa ensete* Gmel., an ornamental plant reaching 9-12 meters in height with very large seeds (2 cm. in diameter). This species has not been observed by the authors.

Ensete glaucum (Roxb.) Cheesman was noted by Blanco (1845), Teodoro (1915), and Quisumbing (1919) to occur sparsely in Luzon, where it is called "Virgen." The plant depicted in Philippine Agric. Rev. 6 (1913) facing p. 413, labeled "Virgen" banana, was identified by Teodoro (1915) as *M. glauca* Roxb., and by Cheesman (1947) as *Ensete glaucum* (Roxb.) Cheesman. The stem of this species is more or less enlarged at the base with very waxy leaf sheaths and large, persistent, green bracts. The large seeds are smooth, about 1 cm. in diameter, with deeply sunken hilum. *Ensete glaucum* has been observed in several places in Laguna province, and is represented among the collection of the College of Agriculture. Cheesman (1947) writes that "possibly several related forms have been confused," and suggests that this species deserves further study.

THE GENUS MUSA L.

The classification of bananas by Cheesman (1947) rather sharply re-groups the sub-genera and species of Baker (1893). *Musa* species are distinguished by Cheesman from those of the genus *Ensete* Horan by their perennial and stooling habit, cylindrical pseudostems, small seeds of irregular shapes, or if globose and smooth much smaller than those of *Ensete* species, and chromosome numbers developed on either the base number $n = 10$ or $n = 11$. In re-grouping the *Musa* subgenera and species, the edibility of the fruit is ignored, as it has been shown to depend largely on the occurrence of parthenocarpy in triploids (Dodds, 1943), and is encountered in only a few of the species.

The revised classification of Cheesman subdivides the genus *Musa* into four sections, systematically distinguished as follows (cf. Cheesman 1947, pp. 108):

A. $n = 11$. Bracts ribbed and rarely polished, convolute or more or less imbricate in bud, commonly revolute on fading.

1. Inflorescence pendent, flowers many to a bract, bracts usually dull-colored or green, pseudostems commonly exceeding 3 meters high ..... Section Eumusa.
2. Inflorescence erect, flowers few to a bract, bracts brightly colored, pseudostems commonly less than 3 meters high ..... Section Rhodochlamys.

B. n = 10. Bracts plane and polished, strongly imbricate, seldom revolute on fading.

3. Seeds sub-globose and smooth, tuberculate or irregularly angulate, commonly with marked elevation opposite to hilum ..... Section Australimusa.

4. Seeds cylindrical or top-shaped, marked with a transverse line or groove, above which they are warted, below usually smooth, internally with large empty chamber corresponding to warted surface area..... Section Callimusa.

Species which are recognized by Cheesman (1947-1953) in each of these sections are as follows:

Eumusa—*M. balbisiana* Colla, *M. acuminata* Colla, *M. banksii* F.v.M., *M. sapientum* L., *M. paradisiaca* L., *M. basjoo* Siebold, *M. nagensium* Prain.

Rhodochlamys—*M. ornata* Roxb., *M. mannii* Wendl., *M. velutina* Wendl., & Drude, *M. sanguinea* Hook. f., *M. rosea* Baker, *M. rubra* Wallich ex Kurz, *M. arrantiaca* Mann., *M. laterite* Cheesman.

Australimusa—*M. textilis* Née, *M. peekelii* Lauterbach, *M. hillii* F.v.M., *M. fehi* Bert. ex Vieill, *M. fitzalani* F.v.M., *M. maclayi* F.v.M., *M. lolodensis* Cheesman.

Callimusa—*M. borneensis* Becc., *M. coccinea* Andr., *M. salacensis* Zoll., *M. violascens* Ridley, *M. campestris* Becc., *M. hirta* Becc.

Geographical distributions of those species are considered in detail by Chakranosti (1951) who considers the Assam-Malay region to be the primary center of origin of the genus. The distribution of Australimusa species is discussed in Brewbaker & Umali (1956).

The seedless triploid varieties are propagated entirely by cuttings, so they can often be easily distinguished by the layman, although genetic differences hardly warrant their taxonomic separation as varieties (e.g., Lacatan and Bungolan—cf. Cheesman, 1933 and Teodoro, 1915).

The Philippine species and varieties of *Musa* were rather comprehensively reviewed by Teodoro in 1915 and Quisumbing in 1919. The keys to species in these two early papers are revised in this paper in accordance with the classification of Cheesman, and are pre-

sented here in rather condensed form. Teodoro and Quisumbing presented well-documented descriptions of Philippine varieties of bananas. While these varieties are recognizable botanically, it is believed that with some exceptions, their recognition as taxonomic varieties is no longer necessary.

KEY TO PHILIPPINE SPECIES OF MUSA

a1. Inflorescence erect, flowers 1-5 per bract

b1. Bracts bright scarlet, persistent, seed nearly cylindrical, 6 mm. long, stem devoid of wax, x = 11 ..... *Musa coccinea*

b2. Bracts pale pink, deciduous, seed nearly globose, stem heavily waxy on upper parts, x = 10 ..... *Musa ornata*

a2. Inflorescence pendent, flowers numerous in a bract

b1. Bracts polished, not ribbed or pruinose, free tepal 3/4 as long as compound tepal, leaf blade unequally rounded at base with one side of lamina shorter than the other, chromosome number x = 10 ..... *Musa textilis*

b2. Bracts rarely polished, commonly ribbed and pruinose, free tepal about 1/2 as long as compound tepal, basal lamina of leaf blade equally rounded, chromosome number x = 11.

c1. Petiole margins upright or spread, peduncle more or less pubescent, bud top-shaped, acute, inner bract surface light-colored at base, bracts commonly lifting one at a time and revolute on fading, fruits relatively long and slender, exhibiting marked geotropic curvature (*acuminata-paradisiaca* type).

d1. Wild, seeded plants with green bracts, slender pseudostem, numerous fruits of 5-10 cm. in length, seed irregularly angulate-depressed, 5-6 mm. broad and 3-4 mm. deep, basal flowers hermaphroditic ..... *Musa banksii*

d2. Cultivated edible bananas, robust, commonly seedless, fruit generally longer than 12 cm.. .. *Musa paradisiaca*

c2. Petiole margins incurved, peduncle not pubescent, but ovate, inner bract surface deep red to base, bracts lifting two or more at a time, fruits generally broad, short, not conspicuously curved, compact, angular, geotropic response evidenced in pedicel of fruit, seed if present subglobose (balbisiana type) ..... *Musa balbisiana*

c3. Cultivated, edible, more or less seedless bananas with characteristics suggesting affinities to both *acuminata-paradisiaca* and *balbisiana* types, but not readily classified in either of these types ..... *Musa sapientum*

Musa coccinea Andrews, Bot. Ret. t. 47 (1797).

This ornamental banana is well known, and is commonly cultivated in the Philippines as the "red-flowered banana." The description of this species is given by Teodoro (1915). A complete taxonomic description is given by Cheesman (1950), who places the species in the section Callimusa by virtue of the cylindrical seed, chromosome number ($n = 10$) and cross-compatibility with other species of that section.

Musa ornata Roxb. Hort. Beng. 19 (1814) et Fl. Ind. 2.488 (1824).

This species is widely distributed in the tropics as an ornamental plant, and was first reported from the Philippines by Quisumbing (1919), who gave a complete description of *M. ornata* plants in the collection of the Department of Agriculture and Natural Resources. The species is represented in the collection of the College of Agriculture from plants which were probably among the introductions described by Quisumbing. Cheesman (1949a) has also described this species in detail, noting that it is the best known species of the section Rhodochlamys ($n = 11$). Its upright inflorescence and pale pink bracts are diagnostic.

Musa textilis Née in Anal. Cienc. Nat. 4 (1801) 123.

Descriptions of *Musa textilis* (abacá or Manila hemp) by Cheesman (1949b), Teodoro (1915), and Copeland (1927) serve to taxonomically identify this well-known crop plant of the section Australimusa. It is discussed in Brewbaker *et al.* (1956), with a description of several closely related species or species hybrids found in the Philippines.

Musa lolodensis Cheesman (Kew Bulletin 1950)

Musa lolodensis is a species of the Australimusa ($n = 10$) section of *Musa* originating from North Halmaheira in the Moluccas south of Mindanao (Cheesman, 1950). It is not known to occur naturally in the Philippines, but is represented in the College of Agriculture nursery by plants grown from seed from The Imperial Col-

lege of Tropical Agriculture (I.C.T.A.). Some description of this species here may be appropriate, since the name has been applied in the Philippines to plants of the *M. banksii-M. acuminata* type, and since the possibility that this species does occur naturally in Mindanao would appear great. The fruits of *M. lolodensis* are dehiscent and orange-red with the free and compound tepals of nearly equal length (4.5 cm.), bracts yellow-brown and more or less convolute, staminodes in female flowers well-formed. In other respects, this species is very similar to *M. textilis.*

Musa banksii F.v. Muel (*sensu* Cheesman, 1948)

The specific epithet *M. banksii* has been applied to the common Philippine saguing maching or monkey banana in Brewbaker and Gorrez (1956). Saguing maching was described by Blanco (1845) as *Musa troglogytarum errans* and later by Teodoro (1915) as *Musa errans* (Blanco) Teodoro. Cheesman (1948a) deemed it probable that *M. errans* (Blanco) Teodoro was a form of *M. acuminata* Colla, and noted the need for further study of these forms in the Philippines. Saguing maching is common in the forests of Laguna province and is distinguished by its large number of tiny, uncurved fruits (15-18 hands, 14-16 fruits per hand), green bracts, and hermaphroditic basal flowers. The last two characters named provide the basis on which *M. banksii* is distinguished from *M. acuminata* and on which saguing maching is presently classified as *M. banksii* (Brewbaker and Gorrez, 1956). The distinction of these species is at present a useful and convenient one. However, further study may reveal that these characters are not sufficient for the separation of *M. banksii* as a species distinct from the ubiquitous *M. acuminata* (Cheesman, 1948), in which case the latter specific epithet would be applicable to monkey banana.

The seeded diploid (2n = 22) *M. acuminata* is a species of unique significance as the probable precursor of a large majority of cultivated seedless (2n = 33) bananas. The *M. paradisiaca* bananas are directly referable in origin to *M. acuminata* and *M. sapientum* forms and are considered to have been derived from hybrids of *M. acuminata* and *M. balbisiana* (Cheesman, 1948).

Musa balbisiana Coll, Mem. Gen. Musa 56 (1820)

This species of the section Eumusa is reported by Cheesman (1948a) as the commonest and most widely distributed of *Musa* spe-

cies. It is ubiquitous in the Philippines, where it shows considerable variation and is used as a fiber plant, as a medicinal plant, as a cooking banana, and for everything from floor waxing to food wrapping. The forms, "pacol" (known to some as *Musa errans* [Blanco] Teodoro), "butuhan" (*M. errans* var. botoan Teodoro), *M. errans* (Blanco) Teodoro var. *basilisae* Quisumbing, "bunlo" (in Camarines Norte) and "inisarog" (in Camarines Sur), *M. sapientum* L. var. *compressa* (Blanco) and most of the other "saba" types of more or less seedless bananas which have been described by Teodoro (1915) and Quisumbing (1919) definitely appear to be forms of the species *M. balbisiana.* Complete descriptions of these species are found in Cheesman (1948) and in Brewbaker *et al.* (1956).

Musa paradisiaca L. Sp. Pl. 1043 and *Musa sapientum* L. Syst. Ed. 10, (1759).

The taxonomic status of the large majority of cultivated edible bananas has a redoubtable historical reputation as a botanical football. Linnaeus originally applied the specific designation *paradisiaca* to a type of banana with persistent bracts of the plantain fruit type (most palatable when cooked) and with evident morphological affinities to the wild diploid species *M. acuminata* Colla.

The species *M. paradisiaca,* section Eumusa, is recognized by Cheesman (1948) as applicable to the entire group of horticultural varieties (seedless triploids with 3n = 33) which have distinct resemblance to *M. acuminata* (Cheesman, 1948a). The latter designation is reserved for wild-seeded diploid forms, although Cheesman admits the distinction of cultigen and wild species to be largely for reasons of practical convenience. The typical *M. paradisiaca,* as pictured by Cheesman (1948-para.), would appear to be most closely represented in the Philippines by the common variety "Morongdato" (Bicol) or "Todlongdato" (Visayan). This variety was described by Teodoro (1915), as *M. sapientum* L. var. *Todlong* (Teodoro), and is noted for its long "finger-like" bananas and persistent male flowers.

M. sapientum was applied by Linnaeus to plants similar to *M. paradisiaca* but with deciduous bracts and edible fruits. Cheesman's observations (1948b) of Ehret's early drawings of the Linnean type specimens of *M. sapientum* led to the conclusion that these showed definite affinities to *M. balbisiana.* Cheesman considers the Linnean

type to be very similar if not identical to a cultigen in the collections of the I.C.T.A., a plant known as the "apple banana" in the Americas. This variety was introduced into the Philippines and subsequently described by Teodoro (1915, p. 397) as *M. sapientum* var. *cubensis* ("Manzana de Cuba"). It resembles almost to the point of identity the well-known Latundan variety, a plant described by Teodoro (1915, p. 397) as *M. sapientum* var. *cinerea* (Blanco) which is a highly preferred table or dessert banana in the Philippines.

It might be well to note here the views of Cheesman *et al.* (1933) concerning the common Philippine variety Lacatan. This excellent table variety is suspected to have originated in the Philippines. Cheesman and co-workers concluded that varieties Lacatan, Bumulan (Philippine "Bungulan" or "Bongolan"), Giant Fig and Masah Hijan were "one and the same variety, best known as Lacatan," and that the entire group of dwarf or Cavendish bananas, usually called *M. cavendishii* (as by Teodoro, 1915, and Quisumbing, 1919), was closely related to the Lacatan assemblage. Later, Cheesman (1934) reported that Lacatan *sensu* Teodoro (1915) was not identical to the tall Cavendish variety known as Lacatan in Trinidad and the Americas, and rejected the use of this name for the varietal assemblage given above. Further study of this and other varieties in the Philippines is definitely needed. The high resistance of the Lacatan *sensu* Cheesman to Panama disease is noteworthy, and is one of the few characters that serve to distinguish Lacatan from Gros Michel, the more common of the two world export bananas.

Cheesman considers that the specific epithet, *Musa sapientum* should be extended to those edible varieties of the section Eumusa which show distinct affinities to both *M. balbisiana* and *M. acuminata*. This distinction is not visualized as being invariably lucid, as the *M. sapientum* types are believed to have originated largely as the result of species hybridization and subsequent ploidy and would be expected to show many different combinations of characters of the parental species. A detailed consideration of the occurrence of parthenocarpy and triploidy in the origin of these cultivated bananas is given by Chakravorti (1951).

Classification of the cultivated edible bananas (partially or completely seedless triploids) is thus reduced to three types—one directly referable to, and included in *M. balbisiana*; the second directly referable to *M. acuminata* and included in the species *M. paradisiaca;* and a third type, *M. sapientum,* which comprises those forms

having a relatively intermediate position between the two more definite entities. Those three types are best represented in the Philippines by Saba, Morongdato, and Latundan, respectively. The characters of these first two groups are reviewed in detail by Cheesman (1948a, b.), and are condensed in the key to species given above. The interrelationships of these Eumusa species are diagrammatically represented in Figure 1.

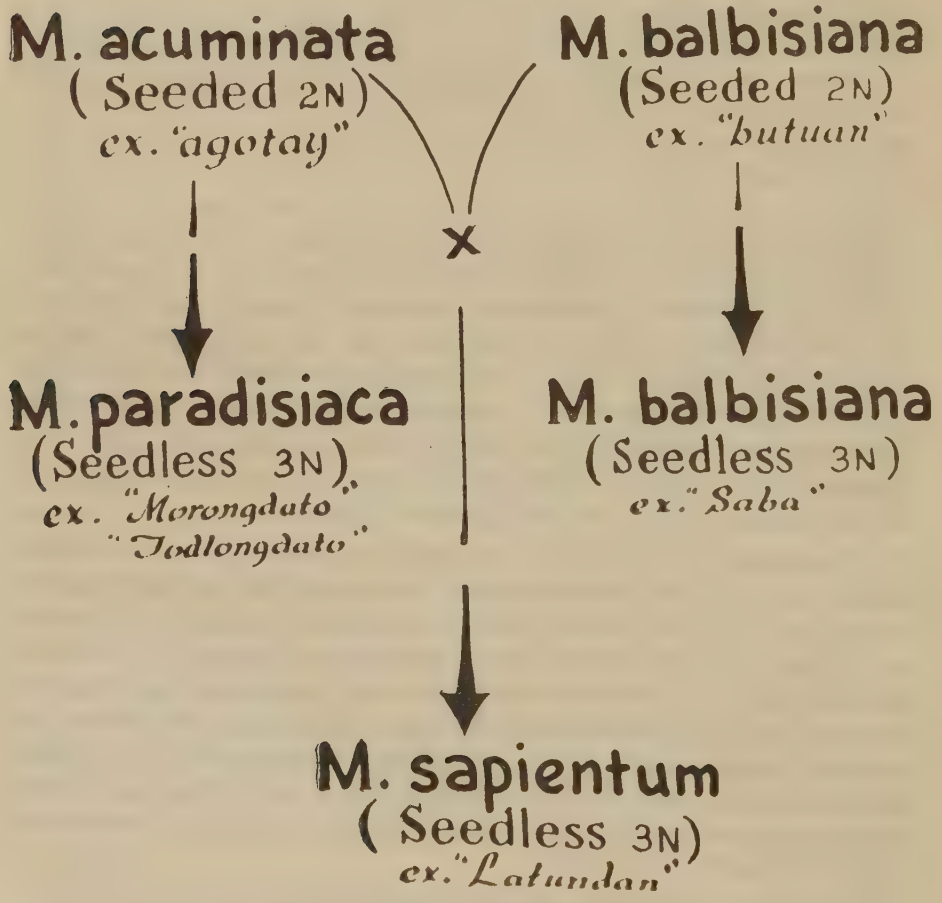


Fig. 1.—A diagram showing the relationships of *Musa acuminata*, *M. balbisiana*, *M. paradisiaca* and *M. sapientum*.

CONCLUSIONS

The following species of the genera *Musa* and *Ensete* (after Cheesman, 1947-1953) have been studied as they occur in nature or as cultigens in the Philippines:

Musa textilis	"abacá," "amoquid"
M. balbisiana	"pacol," "butuhan" types, "saba" types
M. banksii	"saguing maching," "agotay"
M. paradisiaca	edible cultigens—e.g., "Morongdato"
M. sapientum	edible cultigens—e.g., "Latundan"
M. coccinea	red-flowered banana
M. ornata	pink-flowered banana
Ensete glaucum	"Virgen" banana
E. edule	Abyssinian banana

Key to these species and brief descriptions of common forms are presented. It is noted that, following Cheesman, specific epithets such as *Musa errans* (Blanco), *M. Cavendishii*, and *M. sylvestris* Rumph. are no longer valid.

(*Literature cited is given at the end of the third article in this series.*)

CLASSIFICATION OF PHILIPPINE MUSAE II. CANTON AND MINAY, PUTATIVE HYBRID FORMS OF MUSA TEXTILIS NÉE AND MUSA BALBISIANA COLLA [1]

J. L. Brewbaker, D. D. Gorrez, and D. L. Umali

WITH FOUR TEXT FIGURES

The Philippines is recognized as the most probable center of origin of the species *Musa textilis,* source of abacá (Manila hemp) fiber. It is also an area of great diversity in *Musa balbisiana,* a species known in the Philippines by such vernacular names as pacol, butuhan, and saba which apply to common native forms of this species. These forms have been described as *Musa errans* (Teodoro, (1915) and *Musa sapientum* (Quisumbing, 1919), but are taxonomically recognized as *Musa balbisiana* Colla.

The cross-fertile species *M. textilis* and *M. balbisiana* are not separated in the Philippines by any significant geographic or ecological barriers. In regions of overlap in their distributions hybridization has doubtless occurred. Canton and minay which will be discussed in this paper, are suspected natural hybrids of these species. This study was made as part of the Cooperative Abacá Improvement Project of the U.P. College of Agriculture and the Bureau of Plant Industry.

All varieties of *textilis* which have been inoculated with the abacá mosaic virus or subjected to natural infection have proved susceptible, and it is doubtful at present whether resistance to this serious disease can be found within the species. In contrast, all forms of *Musa balbisiana* which have been studied, as well as the suspected natural hybrids of *balbisiana* x *textilis* to be reported have shown either high resistance or complete immunity to the disease. The most promising *modus operandi* in the breeding of mosaic-resistant abacá appears to be that of introducing the genes for resistance from a related species to *M. textilis* . *Musa textilis* is cross-compatible with several *Musa* species, including *M. acuminata, M. balbisiana, M. lolodensis,* and *M. borneensis* (Cheesman, 1949), although such hybrids are often partially or highly sterile. The search

[1] Central Experiment Station Contribution No. 1910.

for naturally occurring fertile hybrid forms with mosaic resistance is considered to be a project of fundamental importance in the current abacá improvement program.

DESCRIPTION OF MUSA SPECIES

The putative hybrid forms which are to be considered showed distinct affinities to both the species *Musa textilis* Née and *Musa balbisiana* Colla. These species occur naturally in Philippine flora and are widespread. In order to facilitate the discussion of forms that follow, the taxonomic descriptions of these species as treated by Cheesman (1948b and 1949c) are given here with data recorded from Philippine varieties. Measurements were made of 75 plants belonging to 34 different varieties of abacá, of which 54 plants had male buds (Gorrez, 1955).

Musa textilis Née (Cheesman 1949, p. 269-270). Section Australimusa (n = 10):

Plant stooling freely, pseudostems 2.0-3.8 (av. 2.6) m. high, 8-20 cm. in diameter at base, green or more or less purplish or even almost black towards base; leaf sheaths and petioles devoid of wax.

Leaf blades oblong, narrowing towards the apex, 1.5-2 meters long (av. 1.9 m.), 40-50 cm. wide (av. 46.7 cm.), narrowly truncate at tip, rounded at base, the two sides unequal at base, midribs green like the lamina, occasionally purplish; petioles 30-50 cm. long, relatively stout and stiff, holding the leaves at a high angle, their margins distinctly developed and incurved, almost covering the adaxial groove above, closely appressed to the pseudostem at base, not becoming scarious.

Inflorescence at first subhorizontal, its peduncle and rachis glabrous or minutely puberulent; sterile bract green, up to 50 cm. long, acute; basal flowers, female, the number of female hands varying from 3-9 (av. 4.4), upper hands male.

Female flowers 6-12 (av. 7.9) per bract in two rows; ovary 5 cm. long, green, glabrous; compound tepal 4 cm. long, 1.2 cm. wide, white with pale green lobes, the lateral lobes oblong-lanceolate, 5 mm. long, with filiform dorsal appendages also 5 mm. long, center lobe also with dorsal appendage but somewhat shorter; free tepal 3.5 cm. long, 2 cm. wide, white, boat-shaped, corrugate in the upper third, with a minute apicula; staminodes about half as long as the styles.

Male bud in advanced blooming oblong-ovoid, from 11-22 (av. 17.1) cm. long, 5-10 (av. 6.8) cm. wide, blunt, the bracts very strongly imbricate, the outermost being only about two-thirds the length of the bud. *Bracts* greenish brown or purplish brown, sometimes green at their rounded tip; outer surface quite plain, shining with polished appearance, inner surface much paler, more or less white at base. Bracts lifting one at a time, but persisting for two or three days after the subtended flowers have dropped, so that there may be several open on the bud at one time; firm in texture, scarcely revolute on fading, but first strongly reflexed and then deciduous; from 6 to 16 (av. 10.7) cm. long, 4 to 9 (av. 6.3) cm. wide.

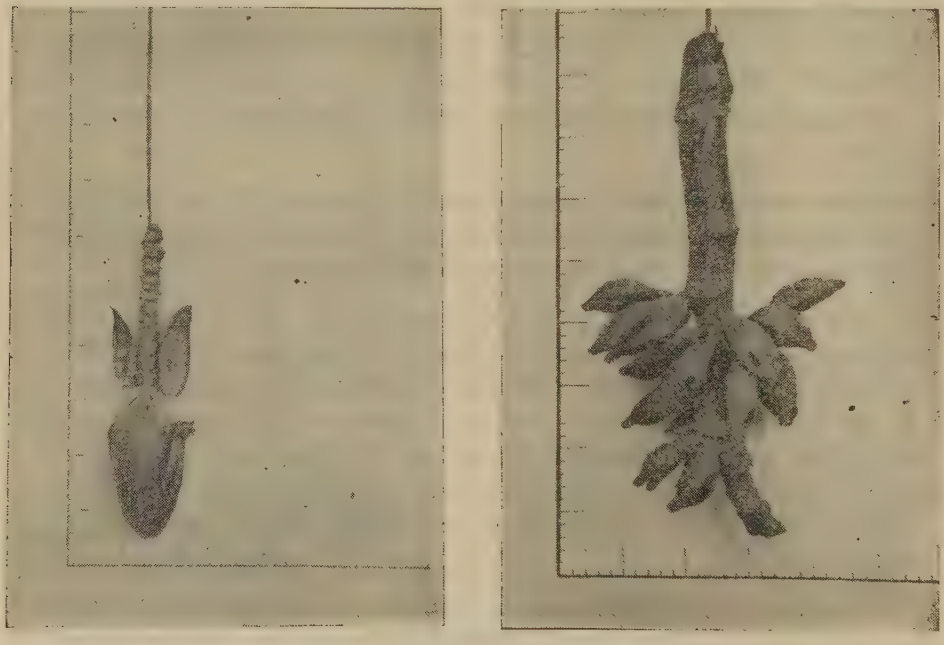


Fig. 1.—*Musa textilis* Née. Left, male bud in advanced blooming; right, fruit bunch approaching maturity. All scales in centimeters.

Male flowers 8-12 (av. 9.3) per bract in two rows; compound tepal 3.8 cm. long, white or cream, the upper part and lobes slightly more yellow, the lobes about 3 mm. long with dorsal filiform appendage 1 mm. long, the accessory teeth nearly as long as the lobes and sometimes also appendaged; free tepal 3.0 cm. long, 1.2 cm. wide, translucent, white, acute, scarcely apiculate; stamens slightly exserted at maturity.

Fruit bunch horizontal, lax. *Individual fruit* 5-7 cm. long (including pedicel), about 2 cm. in diameter at the middle, oblong-ovate or ellipsoidal, obsoletely angled at maturity, narrowed at base into a stout pedicel 1-15 cm. long and abruptly at apex into a broad truncate acumen about 7 mm. long; pericarp 1 mm. thick, ripening yellow; pulp scanty, pale buff in color.

Seed numerous, sub-globose-turbinate, very irregular in shape, usually higher than broad, about 2-3 mm. across and 3-4 mm. high, smooth.

With the exception of alinsanay (Brewbaker and Gorrez, 1956) the great range in varietal type represented by the 34 Philippine varieties of abacá studied was well confined within the limits of taxonomically well-defined and readily distinguished species. In characters such as coloration, number of suckers, size of plant, leaves, male buds, bracts and fruits, number of hands and of fruits per hand—this variation is great and has been used effectively in distinguishing the varieties agronomically. The variation in abacá plants grown from seed is similarly great. Mendiola (1926) records data from such a study, noting the wide range in coloration, vigor, size, etc., among 33 abacá plants grown from seed.

All Philippine varieties of abacá which have been studied cytologically have shown ten pairs of chromosomes which assort regularly at first metaphase of meiosis.

The nomenclatural history of abacá is reviewed in detail by Cheesman (1949 text) and Copeland (1927). Several specific epithets have been applied to abacá, and certain native forms in the Philippines have been suggested to be specifically distinct. Two of these, canton and minay, will be considered later in the discussion of suspected *textilis* x *balbisiana* hybrids.

Alinsanay is one of the unique forms of abacá in the Philippines. It is found over a rather large area of the Camarines provinces at relatively high elevations, and is distinguished particularly by its large number of fruits (ca. 150-200). It is treated in detail in Brewbaker and Gorrez (1956), in which it is suggested to be a derived hybrid of *M. textilis* and *M. banksii* (or *M. acuminata*).

One form that has been mentioned in the literature also deserves mention here. This is the amoquid discussed by Copeland (1927). As Copeland observed, the word amoquid in Bicol refers to mountains (boquid), and is a term loosely applied to abacá-like plants

not under cultivation in the Bicol. So far as the present authors could determine, plants described as amoquid are typical *Musa textilis*, and cannot be considered to represent primitive wild forms of that species. The possibility also exists that the name amoquid is occasionally applied to plants of *Musa banksii* (Brewbaker and Gorrez, 1956).

Musa balbisiana Colla. (Cheesman, 1948-1, 14-15). Section Eumusa (n = 11):

Plant stooling freely; pseudostems robust, up to more than 6 (av. 4.6) m. high, from 15-35 (av. 26.2) cm. in diameter at height of 0.5 m., and from 12-30 (av. 23.3) cm. in diameter at height of 1 m., predominantly yellowish green or green, the upper parts of the leaf-sheaths often with black markings and the lower parts in age often light reddish brown; leaf sheaths and petioles usually more or less pruinose, sometimes heavily so.

Leaf blades oblong, ranging from 2-5 (av. 2.94) m. long, 65 cm. wide, truncate at apex, rounded or slightly cordate at base, green above, paler and more or less glaucous beneath, midribs green, yellowish green or reddish; *petioles* 60 cm. long or longer, strongly concave above, their edges almost meeting over the adaxial channel, margins inconspicuous above, more developed below, where the petiole passes into the leaf-sheath, here closely appressed to the pseudostem, not becoming scarious, often bordered by a black line.

Inflorescence pendulous, its peduncle and rachis glabrous; basal flowers female, the number of female hands ranging from 5-10 (av. 7.3), upper hands male; 13-20 (av. 17.4) female flowers per hand; *male bud* in advanced blooming, broadly ovoid to ellipsoidal, the bracts imbricate at the blunt apex, bud ranging from 11-25 (av. 20.5) cm. long, and from 6-11 (av. 9.8) cm. wide; *bracts* various shades of dark purple, broadly ovate, ranging from 16-24 (av. 18.3) cm. long, and from 7-17 (av. 12.2) cm. wide, rounded at apex, often greenish or yellow at extreme tip; outer surface more or less heavily waxy, longitudinally ribbed; inner surface dark crimson to the base, transversely corrugated between the ribs; several bracts lifted at the same time, exposing several hands of male flowers simultaneously; bracts usually soon deciduous after flowering but occasionally persistent in a withered condition, especially in the later stages of blooming. *Male flowers* from 14-24 (av. 18.7) per bract, in two rows; compound tepal 3.5-6.0 (av. 4.6) cm. long, about 1.2 cm. wide, whitish in ground

color but commonly more or less purplish within, the pigmentation varying from a pale blotch at the base of the tepal to bright reddish purple over most of its length, and showing through to the outside as a pink tinge; upper part of tepal, including the teeth, yellow, varying from pale yellow to dark orange, the teeth about 5 mm. long, the 2 outer with dorsal filiform appendage 1-2 m. long; free tepal about half as long as the compound tepal, ranging from 1.4-2.6 (av. 2.2) cm. long, 1.0-2.5 (av. 1.7) cm. wide, translucent white or pinkish, more or less boat-shaped, obtuse, truncate, or emarginate at apex, with a short apicula; stamens at first as long as the perianth, later exserted. Fruit bunch pendent, generally very compact, the crowded fruits having little room (except in the basal hand) to reflex geotropically and consequently for the most part standing out from the rachis. *Individual fruit* about 10 cm. long, 4 cm. in diameter, more or less distinctly angulate at maturity, rather abruptly narrowed at base into a pedicel of 1-2 cm., and more gradually at apex into a short broad acumen; pericarp about 3 mm. thick, pale yellow at full ripeness, soon blackening; pulp whitish. *Seed* when present black, irregularly globose, scarcely depressed, minutely watery, 5-6 mm. across and 4-5 mm. high.

Distribution: Ceylon, India, Burma, Siam, Malaya, Java, Philippines and New Guinea.

This species of seeded (2n = 22) and seedless (3n = 33) bananas is probably distributed more extensively in the wild throughout the world than any other species in the genus. While certain diploid seeded forms are of value for food, fiber, and assorted uses, only the seedless triploids are commonly cultivated. Cheesman (1948) definitely regards butuhan (*Musa errans* Blanco var. butuhan by Teodoro, 1915) and Pelipia (described as *Musa sapientum* L., variety Pelipia by Quisumbing, 1919) as *Musa balbisiana* types. This classification was based on specimens growing in Trinidad. To these may be added the diploid pacol and triploid sabas of the Philippines.

Butuhan ("botoan," "butuan") is a common Luzon form, so named for its seediness (seed = "buto" in Tagalog), and is quite variable in edibility and seediness of fruits. At one extreme in the range of variability, butuhan merges morphologically with the very seedy, inedible pacol. For convenience, the name butuhan is used here in reference to an entire assemblage of *M. balbisiana*, edible, seeded bananas. Other names are used in certain regions of the islands, such as "Bundo" (Camarines Norte), "Inisarog" (Cama-

rines Sur), and "Paguio" (Visayas). No consistent differences appeared to distinguish these forms. Pacol, a name conspicuous by its absence in the writings of Teodoro (1915) and Quisumbing (1919), was represented in the early collection of the Department of Agriculture at Alabang, Rizal (Saleeby, 1913). Pacol was described by Merrill in 1922 (see Cheesman 1949 text) as the form described by Blanco as *Musa errans* (Blanco) Teodoro, and later authors adopted this designation (Quisumbing and Elayda, 1926; Mendiola, 1926; Umali and Valdez, 1951). That Merrill and later authors should have identified pacol as *Musa errans* (Blanco) Teodoro is understandable in the light of the inadequacy of earlier descriptions. However, Teodoro (1915) and Blanco (1845) applied *M. errans* (*M. troglodytarum errans* of Blanco) to plants with green bracts, green spathe, colorless flowers, glaucous leaves, and very small ("finger-like") fruits, and none of these characters can be observed in pacol. Copeland (1927) recognized that these plants were not pacol and considered them to be a type of abacá.

A study of these plants has been reported in Brewbaker and Gorrez (1956) where it is concluded that the *M. errans* (saguing maching or monkey banana) of Teodoro is actually *M. banksii*. Pacol, on the other hand, is unquestionably *M. balbisiana* (Cheesman, 1948a, Pl. 2, figs. 1, 2, and 3.)

Chromosome studies revealed that pacol has 11 pairs of chromosomes which assort regularly at first metaphase of meiosis (Valmayor *et al.*, 1956).

In the present survey of types known as pacol and butuhan, it was impossible to establish any sort of consistent systematic differences between the two and they are not considered to warrant taxonomic varietal status (table 1). However, the practical distinction of pacol as a form of *M. balbisiana* with less palatable fruit and better fiber than butuhan is a convenient and common one. The use of pacol fiber as an adulterant in abacá is well-known, although it is cultivated much less seldom than butuhan and has no value as food. Pacol was observed as a wild plant in Pampanga (Clark Field) and in southern Albay and Sorsogon, although it is reportedly found more widely. The slightly edible butuhan types appear to be more common in the wild, reportedly from nearly all the provinces on which information could be obtained. The pacol of breeding studies traces back to Albay, in which area this form, with its slightly greater value as a fiber plant, has gained fame and in which it may have originated.

Butuhan is described by Mendiola (1926, p. 238) as probably the most seedy of all Philippine varieties with an average of 200 seeds per fruit. That it is diploid is evidenced by the seediness and high pollen fertility of the plant. The variability in seediness of the butuhan has been noted previously and was also observed in this study. Certain plants produce soft, brownish seeds without embryos, suggesting cytological irregularities. In this connection, it is interesting to note that Wilson (1946) observed anaphase bridges during meiosis of a 22-chromosome *M. balbisiana* plant growing in Trinidad from Philippine seed, presumably a butuhan type.

The seeded variety Pelipia (described as *Musa sapientum* L. var. Pelipia by Quisumbing, 1919) has been mentioned above as a type grown in the Trinidad nurseries from seed sent from the Philippines, and referred to as *Musa balbisiana* by Cheesman (1948). It is reported by Quisumbing from Surigao, and might appear to warrant further study. It is described by Mendiola (1926, p. 239) as having about four seeds per fruit. The description by Quisumbing of plant specimens at his disposal indicated a number of rather unique characters (large flowers, few fruits per hand, broad petiole margins not conspicuously incurved, persistent bracts) which suggest affinities to *M. peekelii* (Cheesman, 1949c). The material received by Cheesman cannot have truly represented the original material of Quisumbing's, if the latter's description is representative.

The saba type (described as *Musa sapientum* L. var. *compressa* [Blanco] by Teodoro, 1915, p. 408) comprises a large and economically important group of cooking bananas in the Philippines (Mendiola, 1926). Saba bananas are generally recognized as robust plants (4-6 m. high), easily grown from suckers, and with only about 5 seeds per fruit (Mendiola, 1926) which are palatable when boiled and often excellent when fried. In all other respects, the saba varieties appear to conform to the description of *Musa balbisiana* given above, with the general exception of the often greater size of the saba plant, leaves, floral bracts, etc. The forms known as "calibo" (Bicol), saba (Laguna), "turangkog" (Bicol) and "sabang Iloko" (Camarines Sur, Cavite, Rizal) were studied and found to overlap with that of butuhan (table 1). However, the saba types produced only a negligible proportion of well-filled pollen grains, and meiotic studies revealed "calibo" and saba (or sabang Tagalog) to be sterile triploids, with $3n = 33$ chromosomes (Valmayor *et al.*, 1956). This ploidy may be considered responsible for the majority of the differ-

ences between the saba bananas and their diploid relatives (pacol and butuhan) in *Musa balbisiana*. It is noteworthy, however, that the saba types appear to be parthenocarpic, producing well-filled fruits in the absence of pollination. This has not been experimentally verified.

TABLE 1.—*Comparative agronomic measurements of Philippine forms of Musa balbisiana Colla.*

CHARACTER	PACOL	BUTUHAN	SABA TYPES
1. No. of plants studied	24	13	20
2. Chromosome number	22	22	33
3. Av. height in cm.	472	528	435
4. Av. diameter in cm.			
(a) 50 cm. from base	22.9	25.5	27.5
(b) 100 cm. from base	20.7	22.6	24.5
5. Leaf dimension in cm.			
(a) length	301	264	302
(b) width	63	67	64
6. Av. no. female hands	8.0	8.2	6.8
7. Av. no. fruits per hand	17.0	16.0	18.0
8. Bud dimension in cm.			
(a) length	20.3	18.6	21.2
(b) width	8.7	8.7	10.5
9. Bract dimension in cm.			
(a length	18.2	17.1	18.7
(b) width	11.9	11.4	12.6
10. No. male flowers per hand	16.8	16.0	20.2
11. Male flower dimension in cm.			
(a) length—compound tepal	4.3	4.9	4.7
(b) length—free tepal	1.9	2.4	2.2
(c) width—free tepal	1.6	1.4	1.8

Teodoro (1915) described sabang Iloko as one of the largest fruited bananas, with fruits of average dimensions of 21 x 7 cm. Those plants observed in the present study produced larger fruits in less compact bunches than the other saba types, although none were of the size noted by Teodoro. Another saba type would appear to be the variety Khai Pet from Siam, described by Quisumbing (1919) as *M. sapientum* var. *Khai* from plants introduced from Siam.

The form Mindanauensis of the now-obsolete species *Musa sylvestris* (Rumphius), is also considered by Cheesman (1949) to be a variety of *M. balbisiana,* although the descriptions (Copeland, 1927) of the several authors describing these forms from Mindanao lack almost everything of being taxonomically adequate. In view of

the occurrence of *M. banksii* in Luzon, it may well be possible that forms of *"Musa sylvestris"* ("Pisang Utan") belong to this species.

PUTATIVE HYBRIDS OF M. BALBISIANA x M. TEXTILIS

In the Philippines two types of *Musa* which show affinities to both *M. balbisiana* and *M. textilis* are the so-called canton and minay. Canton (or cantong) is a highly sterile clone which has been propagated rather widely for use as a fiber plant. Minay is very similar in its botanical characteristics to canton, but may be distinguished by its partial fertility. The following botanical description is applicable to both forms (data from Gorrez, 1955):

M. balbisiana x M. textilis hybrid forms

Plant stooling freely, relatively drought tolerant and disease resistant, pseudostems robust, up to more than 4 (av. 3.2) m. high, from 14-22 (av. 16.1) cm. in diameter at height of 0.5 m., from 10-20 (av. 14.1) cm. in diameter at height of 1 m., leaf-sheaths green, commonly with reddish-brown markings, waxy bloom on young suckers disappearing with age.

Leaf blades ovate-lanceolate or elliptic-lanceolate, from 2.4-3.0 (av. 2.48) m. long, 40-60 (av. 54) cm. wide, truncate at apex, rounded or cordate at base, the two sides of basal lamina commonly unequal, separated at petiole margins by 1-2 cm., green with characteristic reddish-brown tinge; *petioles* 40-50 cm. long, conspicuously reddish on nether surface, their edges distinctly incurved and meeting above the adaxial channel, closely appressed to pseudostem at base, margins more developed below, often bordered by black line. Leaf blades more or less upright, but less so than in abacá.

Inflorescence pendulous, its peduncle and rachis glabrous; basal flowers female, with 3-8 (av. 5.7) hands; 6-14 (av. 10.9) flowers per hand; spadix commonly acute, reddish to green, more or less persistent.

Male bud in late blooming ovoid, from 13-21 (av. 17.0) cm. long, 5.5.-7.6 (av. 7.0) cm. wide, the tip sub-acute to blunt; *bracts* convolute, rarely more or less imbricate, the outermost about three-fourth the length of the bud, from 10-16 (av. 14.9) cm. long, 5-8 cm. broad, ovate, rounded at apex, smooth or faintly ribbed longitudinally, deep purple, outer surface more or less waxy; inner surface dark crimson to base, shining with polished appearance; bracts lifting one or two a day, soon deciduous.

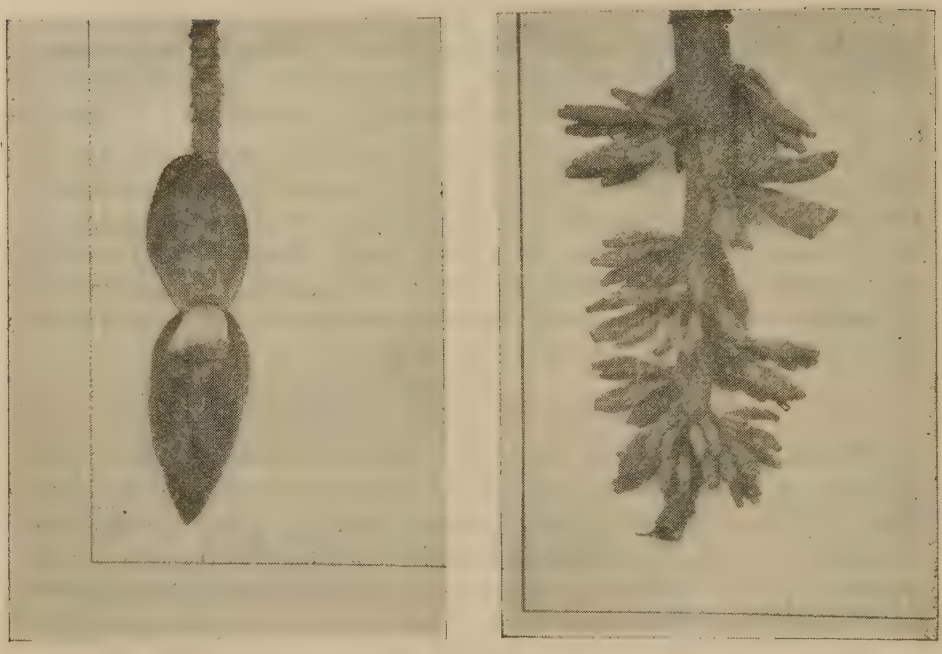


Fig. 2.—Canton, suspected *M. balbisiana* × *M. textilis* hybrid form. Left, male bud in advanced blooming; right, fruit bunch approaching maturity. All scales in centimeters.

Male flowers from 12-18 (av. 14.8) per bract, in two rows, overall length 4.0-5.5 cm.; compound tepal 3.5-4.0 (av. 3.8) cm. long, about 1.0 cm. wide, whitish in ground color with light red pigmentation within, colorless or yellowish at tip; upper part of tepal dentate, with 3 filiform appendages on alternate teeth, teeth 3-4 mm. long; free tepal about 3/4 as long as compound tepal, 2.5-3.2 (av. 2.9) cm. long, 1.2-1.5 (av. 1.3) cm. wide, translucent white or pinkish, apiculate with pronounced shoulders; stamens exserted, more or less revolute.

Fruit bunch pendent, the thin seedless and nearly pulpless fruits showing little or no geotropic response, consequently standing out more or less perpendicularly from rachis. Individual *fruits* seedless or with few seeds, 7-10 cm. long, 1 cm. in diameter sharply 3-5 angulate, narrowed at base to pedicel of 1-2 cm., apex with broad (6-8 cm.) acumen, pericarp about 3 cm. thick, ripening green or pale yellow; pulp if present colorless, gelatinous.

Chromosome number n = 10 in forms studied; spore quartets with 4-10 irregular, angulate cells; pollen rarely if ever filled, seldom dehiscing (Valmayor *et al.*, 1956).

The comparative morphological relationships of canton, minay, *M. textilis* and *M. balbisiana* are listed in table 2.

The relationships are seen to be those in general of the intermediary of canton and minay to the two species, and seem to point clearly to their hybrid origin. Canton and minay show floral and bud dimensions similar to abacá, while with respect to characters

TABLE 2.—*Comparative morphological relationships of canton, minay, M. textilis and M. balbisiana*

	M. TEXTILIS	CANTON & MINAY	M. BALBISIANA
1. No. of plants studied	75	40	40
2. Av. dimension in cm.:			
(a) Height	257	317	458
(b) Diam. at height of 1 m.	9.7	14.1	23.3
(c) Leaf length	194	248	294
3. Av. no. female hands	4.4	5.7	7.3
4. Waxy bloom	none	slight	conspicuous
5. Bract ribbing	"	"	"
6. Leaf color	green	bronze	green
7. Av. number of:			
(a) Male flowers per hand	9.3	14.8	18.7
(b) Female flowers per hand	7.9	10.9	17.4
8. Av. length in cm.:			
(a) Bud	17.1	17.0	20.5
(b) Male bract	10.7	14.9	18.3
9. Av. dimension in cm.:			
(a) Length—compound tepal	3.8	3.8	4.3
(b) Length—free tepal	3.0	2.9	1.9
(c) Width—free tepal	1.2	1.3	1.6
10. Chromosome number	20	20	22

such as ribbing of bracts and presence of waxy bloom, they are more like *M. balbisiana*. The intermediacy of canton and minay in height, diameter, leaf size, number of hands, number of fingers per hand and size of bracts is especially evident in the table above. No significant differences were observed between canton and minay in the characters measured (Gorrez, 1955).

Artificial hybrids of pacol and abacá (*M. balbisiana* x *M. textilis*) growing at the College of Agriculture resemble canton and

show the waxy bloom of the pacol parents and the narrow pointed leaves of the abacá parent. They had not flowered at the time of writing.

First meiotic division of canton, a sterile clone, proceeds with complete regularity, but cell formation is abortive, resulting in various-sized 6-10 daughter cells (Valmayor *et al.*, 1956). The regularity of first meiotic division sugests that the sterility is genetically governed. One report has been made of the appearance of fertile pollen in canton which was used for crosses with abacá at the College, but the progeny have not as yet shown definite evidence of hybridity. Otherwise, canton has been extensively crossed to both abacá and pacol (*M. balbisiana*) without success (Umali and Valdez, 1951).

The small variation observed in canton plants in the provinces of Laguna and Albay suggests that they have been derived from a single clone. The place of origin of canton is most likely the province of Albay in the Bicol. The plant produces a rather strong, rough, brownish fiber which burns down to a gray ash, curls conspicuously in 25% NaOH, and which is used for native products and misused as an adulterant of abacá fiber. Percentage extraction is less than 0.4% which is reportedly better than that of pacol. Canton fiber production is centered in the vicinities of Bagacay and Rapu-rapu Island, Albay.

Canton was designated *Musa cantoni* by Quisumbing and Elayda (1927) without taxonomic description, and the name may now be discarded. It shows remarkably distinct affinities to *M. textilis* and *M. balbisiana* and generally falls in an intermediate position between these species in quantitative characters. The form pacol is suggestively the *M. balbisiana* parent of canton. Cheesman (1949 text) remarks that pictures of canton resemble artificial hybrids of *M. balbisiana* x *M. textilis* growing in Trinidad. The chromosome number of canton suggests it to be a derived hybrid, perhaps from a backcross of the species hybrid to *M. textilis*. Its aggressive vigor, mosaic resistance, drought tolerance, and high stooling capacity have given it a redoubtable fame as a cogon grass competitor in the Philippines.

Minay is a form originating near Libon, Albay, brought by Mr. A. Pasco to the Guinobatan Abacá Station in 1938. It produces occasional well-filled pollen grains and seed, and has been crossed with abacá (with the latter as male parent) at Guinobatan. Minay differs from canton in having a generally more intense coloration in leaves,

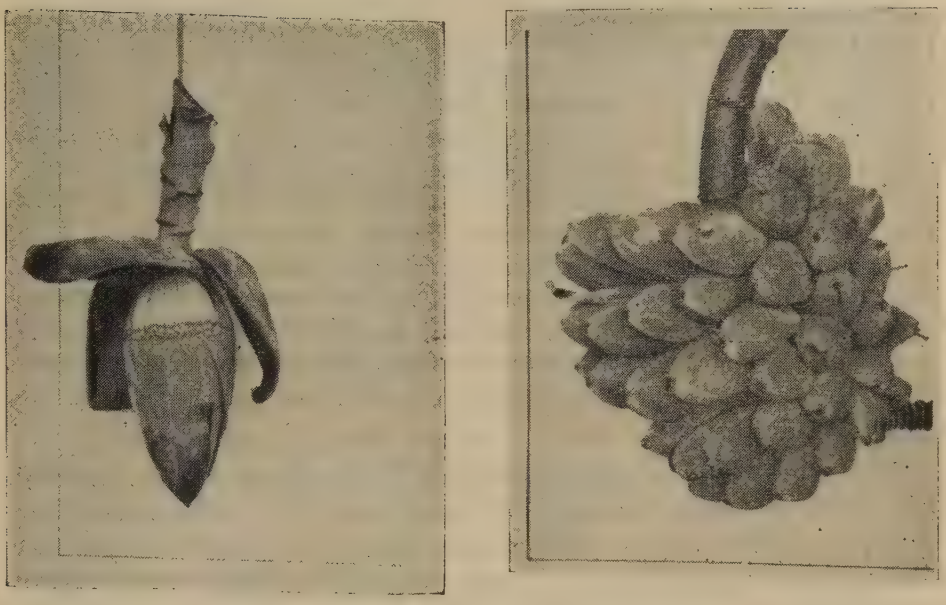


Fig. 3.—Pacol. Left, male bud in advanced blooming; right, fruit bunch approaching maturity. All scales in centimeters.

midribs and tepals—but the two are otherwise quite indistinguishable. At first meiotic division, minay shows occasional anaphase bridges and fragments suggestively attributable to crossing-over in paracentric inversion. Cell wall formation is more regular than in canton, but spore quartet irregularities are commonplace and result in over 99% pollen abortion (Valmayor *et al.*, 1956).

Abacá x minay hybrid families grown at the Guinobatan Abacá Experiment Station, Albay, exhibit great variability, with a high proportion of the plants being stunted, chlorotic, or otherwise abnormal. All hybrids have the leaf and midrib coloration of minay, and floral size characteristics of this parent. Their fiber quality appears to be decidedly inferior to that of the abacá parents. Some abacá x minay hybrids have reportedly shown a susceptibility to mosaic at the Davao Abacá Experiment Station.

It is rather clearly evidenced by such forms as canton and minay that *M. balbisiana* and *M. textilis* have hybridized in the Philippines, and it may be anticipated that further study will reveal an array of hybrid forms of these species. The observation that artificial hybridization proceeds more effectively when *M. textilis* is the male

parent (Umali and Valdez, 1951; Cheesman, personal communication) provokes some speculation on the nature of genetic introgression from these hybrids. Since immediate *balbisiana* x *textilis* hybrids having 2n = 21 chromosomes may be expected to be relatively sterile and to produce few good pollen grains, those F_1's most probably will have been ineffective as male parents in backcrosses. However, it is highly probable that occasional seed will form on such hybrids. That the 20-chromosome parent (*M. textilis*) might be a more effective male parent than the 22-chromosome *M. balbisiana* in these crosses is suggested by the fact that in crosses of abacá (2n = 20 and pacol (2n = 22), the seed set is much better when abacá is used as male parent. It follows that introgression of genes from *balbisiana* to *textilis* in nature might proceed more readily than in the opposite direction.

This may be of some importance to the abacá breeder seeking to introduce mosaic resistance (a character of all *M. balbisiana* forms studied) into *M. textilis*. In regions where these species overlap and where such hybrid forms as canton and minay occur, it seems highly probable that abacá-like forms having resistance to mosaic might be located.

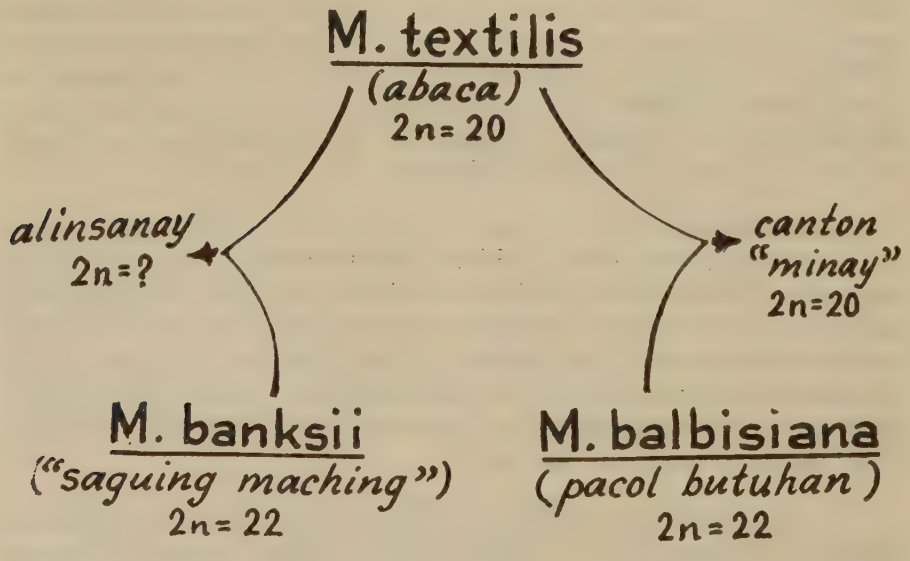


Fig. 4.—A diagram showing the relationships of abacá, minay, pacol, saguing maching and their respective suspected hybrids canton and alinsanay.

CONCLUSIONS

Morphological studies were made in the field of 34 varieties of *Musa textilis*, eight forms attributed to the species *Musa balbisiana*, and two putative interspecific hybrids, canton and minay. Diploid-seeded types classified in the species *M. balbisiana* were pacol, butuhan, bunlo and inisarog; triploid types classified in this species were the saba types—sabang Tagalog, sabang Iloko, calibo and Turangkog.

Canton and minay, both indigenous to the province of Albay in southern Luzon and with 2n = 20 chromosomes, exhibit very similar combination of characters of the two species *M. textilis* (n = 10) and *M. balbisiana* (n = 11) and are suggested to be derived hybrids of these species.

Consideration is given to their possible modes of origin, and to their value to the plant breeder. In view of the resistance of canton and minay to abacá mosaic, their potential value is great.

(Literature citations are given at the end of the third article in this series.)

CLASSIFICATION OF PHILIPPINE MUSAE III. (A) SAGUING MACHING (*MUSA BANKSII* F.V.M.) (B) ALINSANAY, A PUTATIVE HYBRID OF *M. TEXTILIS* AND *M. BANKSII* [1]

J. L. Brewbaker and D. D. Gorrez

WITH TWO TEXT FIGURES

(A) SAGUING MACHING (*MUSA BANKSII* F.V.M.)

Musa banksii F.v. Muell is a species which is distinguished by a characteristic unique among Musae—that of hermaphroditic basal flowers. The flowers in basal hands of *M. banksii* are not actually "perfect," but have from 2-4 of the five stamens fully developed and produce sufficient pollen to insure immediate self-pollination. This major character serves to separate *M. banksii* from the more generally occurring *M. acuminata* Colla. The specific separation of these two may be found upon further study to be inadvisable taxonomically, but its recognition appears advisable until more information can be brought to bear on the systematics of these species.

Saguing maching is a common wild banana in Central Luzon. It was first described by Blanco in 1845 as *Musa troglodytarum* L. var. errans Blanco. Teodoro (1915) recognized that Linnaeus' *M. troglodytarum* was based on a form with erect inflorescence, unlike saguing maching (see Cheesman—fehi 1949) and renamed saguing maching *Musa errans* (Blanco) Teodoro. This specific epithet later became associated with pacol, a form classified as *M. balbisiana* in an accompanying paper and in very few respects similar to saguing maching. During the present study the monkey banana was observed growing above 100 m. in the deep rain forests of Laguna province where it appeared most commonly in grassy clearings. The following description is based on plants on the slopes of Mt. Makiling in Laguna province (cf. Cheesman, 1949, and Teodoro, 1915).

MUSA BANKSII F.v. Muell., Saguing maching:

Plant stooling freely, habitat sylvan; pseudostems 3.0-4.5 meters high, 25-30 cm. in diameter at height of 50 cm., green or more or

[1] Central Experiment Station Contribution No. 1911.

less purplish, black brown with age; leaf sheaths and petioles, glaucous, green. Fiber strips poorly, longitudinally weak, stems transversely very tough.

Leaf blades oblong, 2.5-4 m. long, 50-70 cm. wide, truncate at tip, rounded at base, with basal lamina equal, green, glaucous, midribs green; *petioles* 50-90 cm. long, their margins almost erect, leaving an open adaxial channel, rather lax, closely appressed to pseudostem where margins flare and become more or less blackened and scarious.

Inflorescence sub-horizontal or pendent, its peduncle and rachis thickly pubescent with short brown hairs, basal *flowers hermaphrodite*, the number of hands from 15-17, upper hands male. Spadix acute, green, 50-60 cm. long.

Perfect flowers from 20-28 per bract in two rows; 2 or 3 stamens perfectly developed in flowers of all basal bracts, shedding abundant pollen, remaining stamens more or less rudimentary (staminodal); development of staminodes into well-formed stamens taking place in the apical, 5-7 hands preceding the male flowers. Subtending *bracts* long (30-35 cm.) narrow (9-11 cm.), green, conspicuously ribbed longitudinally, transversely corrugated between the ribs, *compound tepal* about 3.4 cm. long, 1.2 cm. wide, translucent, yellow-tipped, deeply lobed, the outer two lobes acute and 10-11 mm. long, central three lobes fused with outer two of these appearing as serrations about 4 mm. from tip of central lobe; *free tepal* translucent, boat-shaped, rounded at tip with faint shoulders, about half as long as compound tepal; stigma broad, flattened, slightly bifurcate, upper part of style red-speckled; ovary pale green, distinctly 3-5 angled, glabrous above, minutely pubescent at base.

Male bud in advanced blooming ovoid to top-shaped, acute, the bracts convolute, reaching the tip of bud; bracts pale yellowish, green turning red-brown on fading, longitudinally ribbed, transversely corrugated between the ribs, acute at tips, glaucous, inner surface light green. One bract lifted at a time, not conspicuously revolute on fading, deciduous.

Male flowers about 20 per bract in two rows; tepals similar in length and color to those of female flowers; compound tepal yellow at tip, lobed, with outer lobes only 4-6 mm. long, tipped with a short filament, inner 3 lobes equal in length, 3-4 mm. long; free tepal boat-shaped, acutely tipped with more or less prominent shoulders; stamens at first about as long as compound tepal, later exserted, colorless, stigma and ovary greatly reduced.

Fig. 1.—Saguing maching. Left, inflorescence at early stage of blooming, showing some of the hermaphroditic basal flowers; center, male bud in advanced blooming; and right, fruit bunch at early stage of maturity. All scales in centimeters.

Fruit bunch asymmetrical if borne subhorizontally, regularly symmetric when pendent; the 300-350 fruits and pedicels exhibiting marked geotropic curvature. Individual fruits very seedy, 8-12 cm. long, 1.3-1.6 cm. in diameter, conspicuously 4-5 angled when immature but only obsoletely angulate when mature, abruptly narrowed at the base into a pedicel of 1-1.5 cm. (minutely pubescent) and at the apex into a conspicuous acumen 6-8 mm. long; pericarp about 2 mm. thick, yellow-green at ripeness, pulp nearly absent, whitish.

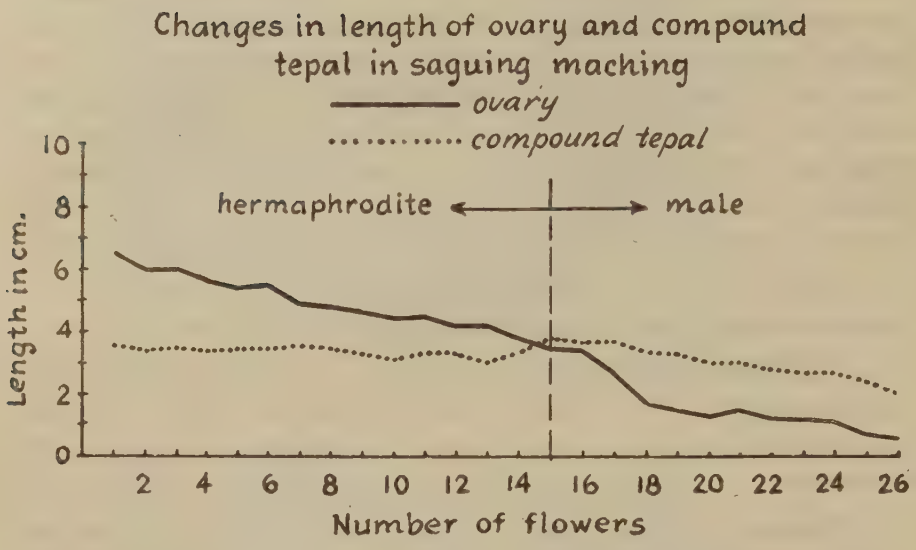
Seeds dull black, commonly more or less warty, irregularly angulate, strongly flattened, 6-8 mm. broad and 3-4 mm. high.

The plants described here appear to be quite similar to the plant described as *Musa banksii* by Cheesman, a clone growing at Trinidad and labelled I.R. 139, obtained from the Bloomfield River area in Queensland.

However, the forms differ widely in the number of flowers per hand and number of hermaphroditic hands. The Queensland form is reported as having about 10 hermaphroditic flowers and 10-15 male flowers per bract and less than 8 hermaphroditic hands, while saguing maching produces as many as 350 fruits (from 15-17 hermaphroditic hands with 20 or more flowers per hand). Cheesman records that *M. banksii* introductions at Trinidad did not grow vigorously and his description was based on only one surviving plant. Thus, the discrepancy in number of fruits may be accounted for by environmental differences although it appears that number of flowers per hand is not too sensitive to environmental variation. Cheesman's description of *M. acuminata* (female hands varying up to about 10 with 16-20 flowers per hand) more closely approximates saguing maching's fruitfulness.

Saguing maching differs from *M. accuminata* Colla *sensu* Cheesman (1948a.) in its hermaphroditic basal flowers, its green bracts and its greater number of fruits. Only the first of these would appear to have taxonomic importance at the species level.

Studies made of the floral characters of saguing maching revealed that about 17 hands of the basal flowers are hermaphroditic and the rest are male flowers. The relative changes on the length of the ovary and tepal are shown in the graph following:



A red-bracted form of *M. banksii* from Samoa (I.C.T.A. collection I.R. 123) is recognized by Cheesman (1948d) as a named variety. Although reports of red bracts in saguing maching in the Philippines were received, no red-bracted forms were observed in this study.

Evidence of the existence of forms similar to Central Luzon's saguing maching in other regions of the Philippines was obtained in the present study. One of these forms was the elusive agotay (Copeland, 1927) from the Bicol which the authors were unable to locate in the field. The fruit bunch and male bud of one plant of agotay growing near Camalig, Albay, were sent to College from the Guinobatan Abacá Station. The fruit bunch obtained had 12 hands and about 14-16 fruits per hand and the male bracts were waxy on the outer surface. In other respects, these specimens were identical to saguing maching. Similarly, fruit bunch specimens brought from Davao Abacá Experiment Station of a form masquerading as *Musa lolodensis* were identical to those of saguing maching. This form reportedly had hermaphroditic basal flowers.

Should *M. banksii* be reduced to the status of a named variety of the widespread and polymorphic species *M. acuminata?* The hermaphroditic and many-flowered saguing maching may play a role of some significance in answering this question. Cheesman (1948)

has described the situation as follows: "Both type and variety (*M. banksii*) cross readily with forms of *M. acuminata* Colla and give fertile hybrids. On this ground, as well as on consideration of the many close resemblances between the species in habit and floral characters, it is very doubtful whether *M. banksii* ought to be maintained as a species at all. For the present it may be maintained for convenience, but intermediate forms may be discovered in New Guinea or the Molluccas connecting it so closely with the polymorphic *M. acuminata* assemblage that it has to be reduced to varietal status. On present evidence we regard it rather as 'replacing' typical *M. acuminata* on the southeastern extremity of the range of that species, but its genotypic differentiation is evidently slight."

Saguing maching presently stands as a sort of connecting link between the Samoan-Queensland *M. banksii* and the *M. acuminata* of the Malay Archipelago and westward. It is set apart from *M. acuminata* by its hermaphroditic flowers and green bracts, and differs from *M. banksii* in its large number of fruits and flowers per hand. A detailed study of *M. banksii-M. acuminata* forms throughout the Philippines and neighboring islands is clearly needed to establish with certainty the nomenclature of these forms.

(B) ALINSANAY, A PUTATIVE HYBRID OF *MUSA TEXTILIS* NÉE and *M. BANKSII* F. V. MUELL.

Alinsanay is a "wild abacá" of the rain forests in Camarines provinces. Although its suckering is not good, its ability to survive in the jungle is impressive. In general appearance, it could readily be mistaken as a robust red-stalked abacá, but a number of characters serve to distinguish it from *M. textilis*. The most prominent of these are its large number of thin, geotropically reflexed fruits, its erect petiole margins, green bracts, short free tepals (1/2 the length of compound tepals), long acute bud, and heavy pubescence of peduncle. Each of these characters could be attributed to *M. banksii,* and have led to the hypothesis of hybrid background of alinsanay. More explicitly, alinsanay is a form suggestively arising from the introgression of *M. banksii* (*M. acuminata*?) genes into *M. textilis*.

The following description of alinsanay is based on plants along the Daet (Camarines Norte)—Sipocot (Camarines Sur) road:

Alinsanay—putative hybrid form of *M. textilis* × *M. banksii*.

Plant stooling; pseudostems 2.5-4.0 meters high, 20-30 cm. in diameter at base, deep reddish purple; leaf-sheath and petioles glaucous, green.

Leaf blades oblong, 3-4 m. long, 40-55 cm. wide, truncate at apex, rounded at base, with unequal basal lamina, green, glaucous, midribs green; *petioles* 50-60 cm. long, their margin almost erect, leaving an open adaxial channel, rather upright as in abacá, closely appressed to the pseudostem.

Inflorescence sub-horizontal, its peduncle and rachis thickly pubescent with brown hairs, flowers in the 10-16 basal hands female, upper hands male.

Fig. 2.—"Alinsanay," putative hybrid form of *M. textilis* × *M. banksii*. Left, male bud in advanced blooming and bract showing deep reddish purple inner surface; right, fruit bunch approaching maturity.

Female flowers from 12-23 per hand (average 16) in two rows; compound tepal white, tips green with filiform appendages; free tepal white, about half as long as compound tepal.

Male bud in advanced blooming ovoid, more or less acute, the bracts imbricate, outer surface green with purple edges, about two-thirds of the length of the bud, not conspicuously ribbed, sub-acute at tips, glaucous, inner surface deep reddish purple at tip and gradually becoming lighter at basal end. One bract lifted at a time, deciduous.

Male flowers per bract from 8-12 (average 10) in two rows, from 5-6 cm. long; compound tepal from 4.0-4.8 cm. long, with an average of 4.5 cm.; white, tips green with 3 filiform appendages about 3-4 mm. long, the center filiform usually a little bit shorter; free tepal from 2.5-3.0 cm. long with an average of 2.7 cm., from 1.0-1.3 cm. wide with an average of 1.1 cm. boat-shaped, white, apiculate.

Fruit bunch asymmetrical, fruits and pedicels exhibiting marked geotropic reflex. Individual fruits very seedy, 10-12 cm. long, 2.0-2.3 cm. in diameter, conspicuously 4-5 angled, abruptly narrowing at the base into a pedicel of 1.5 cm. long, and at the apex into a conspicuous acumen; pericarp about 2 mm. thick, green at ripening, pulp nearly absent, white; fruits heavily seeded.

TABLE 1.—*Comparative morphological relationships of alinsanay, M. textilis and M. Banksii*

	M. TEXTILIS (Abacá)	ALINSANAY	M. BANKSII (Saguing maching)
1. Dimension in cm.			
(a) height	200–380	250–400	300–450
(b) diameter at 50 cm. from base	8–20	20–30	25–30
(c) leaf sheath	150–200	300–400	300–400
2. Av. no. female hands	4.4	12.5	16.0
3. Pubescence of peduncle	none or slight	heavy	heavy
4. Bract ribbing	none	slight	conspicuous
5. Color of stem	red-purple or green	red-purple	green
6. Av. no.			
(a) male flowers per hand	9.3	10.2	20.0
(b) female flowers per hand	7.9	16.0	24.0
7. Av. length in cm.			
(a) bud	12.1	16.6	16.5
(b) male bract	10.7	11.9	11.5
8. Av. dimension in cm.			
(a) length—compound tepal	3.8	4.5	3.3
(b) length—free tepal	3.0	2.7	1.5
(c) width—free tepal	1.2	1.1	0.8

Seeds black, flattened, more or less smooth, 3-4 mm. in diameter and 5-7 mm. high.

Specimens of alinsanay have been planted at the College and the Guinobatan Abacá Experiment Station. The comparative morphological relationships of alinsanay and *M. textilis* and *M. banksii* (saguing maching) are given in table 1.

It seems evident from these comparisons that alinsanay may be a derived hybrid of these two species. If this is the case, seediness and apparent high fertility is rather unusual, as *M. textilis* has 20 chromosomes and *M. banksii,* 22. Direct hybrids of these species would have 21 chromosomes and be partially if not completely sterile. Pending the chromosome counts of alinsanay, it is suggestively a 20-chromosome form resulting from the backcrossing to abacá of species hybrids, as has been suggested for canton and minay in an accompanying paper.

The rain forests that once carpeted southern Luzon have been largely cleared in the last two centuries for lumber and for the coconut plantations. The backbone of the Bicol region is a range of low hills connecting Mt. Banahaw in Laguna with Mt. Mayon in Albay. Throughout the remnant forests on these hills may be seen the ubiquitous *Musa balbisiana,* represented in the south by inedible and more generally throughout the Bicol by more or less edible seeded butuhan types (Brewbaker, Gorrez and Umali, 1956). *Musa textilis* which is suggested to have originated in the Bicol region is most widely cultivated in the southern part of this region. *Musa banksii* (saguing maching) is known definitely only from provinces (Laguna, Rizal) immediately north of the Bicol, although the form agotay of Albay in the Bicol and Leyte-Samar islands southeast of the Bicol may belong to this species.

This triangle of potentially interbreeding species is pictured in figure 1 (page 242), and the geographical locations of species and putative hybrids in figure 2 (page 246). Canton and minay (see preceding article) are considered to be hybrid forms representing the introgression of *balbisiana* genes into *textilis* while alinsanay is believed to represent the introgression of *banksii* genes into *textilis.* It is anticipated that further study in regions of geographical contiguity of these species will reveal other hybrid forms. This study would appear to be one of great value in setting a foundation for the breeding of higher-yielding and disease-resistant abacá.

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(g) Musa itinerans Cheesman—Kew Bull. No. 1, 1949; 23-24.
(h) Musa ornata Roxb.—Kew Bull. No. 1, 1949; 24-27.
(i) Musa sanguinea Hook.—Kew Bull. No. 2, 1949; 133-135.
(j) Musa velutina Wendl.—Kew Bull. No. 2, 1949; 135-137.
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(l) Musa textilis Née—Kew Bull. No. 3, 1949; 267-272.
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(n) Musa peekelii Lauterbach—Kew Bull. No. 4, 1949; 450-452.
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A CYTOLOGICAL STUDY OF ABACÁ AND ITS RELATIVES [1]

RAMON V. VALMAYOR, ELEUTERIO M. MENDOZA
and VICTOR E. MILLARE [2]

WITH TWO TEXT FIGURES

Abacá varieties Maguindanao, Bungolanon, Putian, and Binukid were found to be fertile diploids with normal meiosis and a gametic chromosome number of 10.

Canton, a suspected natural hybrid of *Musa textilis* and *Musa balbisiana*, has 10 pairs of chromosomes and appears to be completely regular in early meiosis. Cell breakdown begins immediately following first meiotic division and results in aborted spore quartets and complete sterility of the pollen. It is suggested that this sterility is a genetically controlled character.

Minay, similarly suspected to be a *M. textilis* × *M. balbisiana* hybrid, has 10 pairs of chromosomes. Chromosome irregularities at anaphase I suggest the presence of inversions and lead to complete abortion of pollen.

Pacol (*Musa balbisiana* Colla.) has 11 pairs of chromosomes and is completely normal meiotically. It is seeded and has well-filled and regular pollen grains.

Saba (*Musa balbisiana* Colla.) is a triploid with 33 chromosomes. Irregularities at metaphase I and anaphase I include bridges, fragments, and laggards. The pollen grains are mostly empty and irregular.

The main objective of abacá breeding at the present time is to produce a variety that is resistant to mosaic. A knowledge of the cytology of abacá and its relatives would be of value in understanding their cytotaxonomic and fertility relations and in evaluating their utility in the breeding program.

Specimens of abacá (*Musa textilis* Née) varieties Maguindanao, Bungolanon, Putian, and Binukid were collected from the nursery of the UP College of Agriculture and Central Experiment Station. Canton, minay, pacol, and saba which so far are considered the most promising parental materials for breeding mosaic-resistant abacá were obtained from the same source and from the Economic Garden in Los Baños and the Guinobatan Abacá Experiment Sta-

[1] Central Experiment Station Contribution No. 1912.
[2] The writers thank Dr. J. L. Brewbaker, former visiting Cornell professor, and Dr. D. L. Umali of the Division of Plant Breeding, for their assistance in conducting this project.

tion. All the specimens were studied for chromosome number and behavior during microsporogenesis in the Plant Breeding Division from November, 1953, to October, 1955.

MATERIALS AND TECHNIQUES

Botanical descriptions of canton and "minay" plants are given in an accompanying paper (Brewbaker, Gorrez, and Umali, 1956). While the canton plants studied were never found to produce seed, the minay fruits were occasionally found with one or two seeds out of a possible 200-400.

Pacol and saba are common Philippine bananas which are classified as members of the species *Musa balbisiana* Colla. Pacol is seedy, inedible and has a rather tough fiber. Saba, of which there are several asexually propagated forms in the Philippines, is essentially seedless, is edible primarily as cooking banana, and has poor fiber.

Canton and minay which are suspected natural hybrids of pacol and abacá generally have the same botanical characteristics except for the occasional production of seeds and deeper coloration of the stem and leaves in the latter. Both have poor fiber, are good stoolers, vigorous and fast-growing, drought resistant and thrive well in places where abacá would not grow profitably.

Acetocarmine smear technique. Male buds were collected at various hours of the day and fixed in freshly prepared Carnoy's 3:1 solution. They were transferred from the fixative to 70 per cent alcohol after 24 to 48 hours. Cytological examinations of the microsporocytes were made according to the standard acetocarmine smear technique described by Smith (1947).

Root-tip smear technique. Root tips from healthy plants were cleaned and treated with oxyquinoline. They were placed on a watch glass containing a mixture of one part HCl and nine parts acetocarmine or aceto-orcein. The glass was heated over a flame until the root tips were soft. The tips were then placed on a glass slide and macerated with a cover glass.

EXPERIMENTAL RESULTS

Meiosis

Abacá. The four varieties of abacá had a haploid chromosome number of 10.

Meiosis of the four varieties was normal and regular. In the various stages of prophase I the nucleolus showed very distinctly.

Although the chromosomes became noticeably thicker and shorter as they progressed from the earliest stage of prophase I to diakinesis, their structure, because of their smallness, could not be defined for karyotypic differentiation.

At metaphase I the achromatic figure was formed and the tetrads were countable as they became arranged at the metaphase plate. At late anaphase the chromosome count was the same. The polar groups of chromosomes at telophase I did not show a discernible telophasic transformation; the transformation did not progress far enough to form the characteristic metabolic nuclei. Cytokinesis occurred after division I. At prophase II the chromosomes were at once discernible because they were already compact and deeply stained. The nucleolus was very much reduced. At metaphase II the dyads of the two daughter nuclei took their positions at the equator of the new achromatic figure. The chromosome count for all varieties at this stage was the same. At anaphase II the chromatids of each dyad moved in opposite directions to the spindle poles. At telophase II the four groups of chromosomes were formed as a quartet of nuclei, each with one complete genome of 10 chromosomes. The pollen grains that eventually developed were round, uniform in size, and well-filled. Their normal cytological behavior explains their fertility.

Canton. The most characteristic feature of the early prophase nucleus was the presence of a single, large, deeply staining nucleolus (fig. 1a). The chromosomes did not stain well during the prophase stages although occasional chromosomes could be seen clearly enough to be measured at pachytene. One chromosome was measured with a length of 20 microns with its centromere located 5 microns from one end. In general, chromosomes at late pachytene, diplotene, and diakinesis were not sharply defined.

Chromosome counts at metaphase showed n = 10 in all countable plates. No multivalents or fragmentation was observed.

As meiosis progressed from first metaphase to first anaphase, the chromosomes segregated without apparent irregularity (fig. 2a). Separation was normal as daughter chromatid pairs passed to opposite poles of the division spindles. Irregularities were first observed at telophase. As the new cell wall formed to divide the microsporocyte into halves, several particles of micro-cells were formed between the two daughter cells. Elaboration of cell wall between daughter cells resulted in grossly enlarged cell partitions (fig. 1b).

After a brief interphase, the second meiotic division followed, producing spore quartets ranging from 4 to 10 irregular cells (fig.

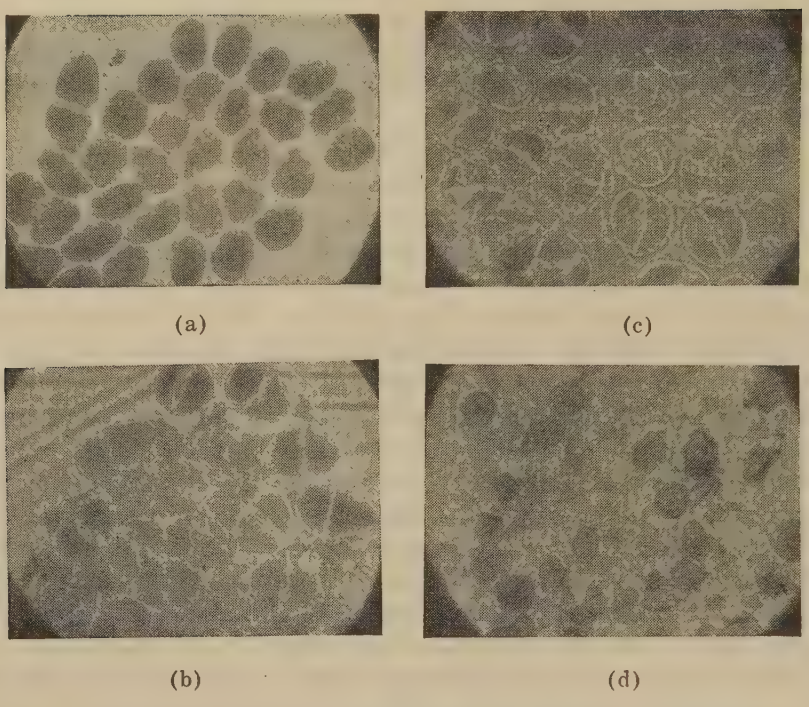

Fig. 1.—Different stages of pollen development in canton (114×): (a) early prophase nucleus, (b) faulty cell wall formation at telophase, (c) irregular spore quartet, and (d) shrivelled, empty, and irregular pollen grains of canton. (*Photographed by the Photographic Division, College of Agriculture.*)

1c). No counts were made during the second meiotic division because the chromosomes did not stain well in these stages. Some of the cells were so small that it was very difficult to make an accurate count of distribution of number of cells per tetrad. The resulting pollen grains were empty, shriveled, and irregular (fig. 1d).

Minay. Early meiotic figures from minay were identical to those from canton. Ten chromosome pairs were observed in all metaphase I plates. At anaphase I, however, minay cells invariably showed from one to three chromatic bridges. Anaphasic bridges were of the type commonly attributed to paracentric inversions, and several bridges were observed in association with minute (acentric) fragments (fig. 2b). No further abnormalities such as translocation-multivalents were evident in the cells studied.

The inversion bridges apparently were not persistent, and cell wall elaboration following first meiotic division appeared normal. Although it was difficult to ascertain the degree of chromosomal reg-

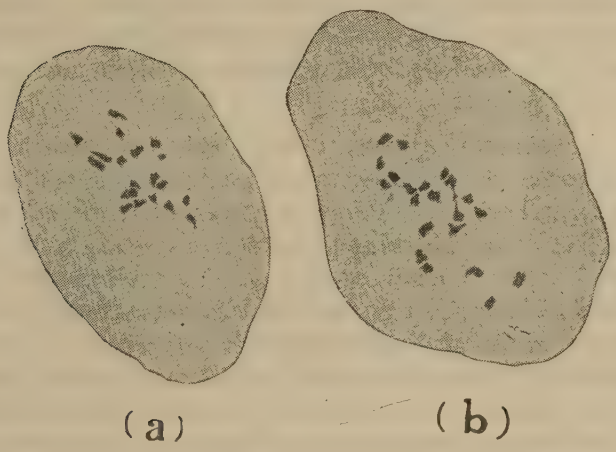

Fig. 2.—Camera lucida drawing showing (a) normal segregation of chromosomes of canton at anaphase I and (b), abnormality of minay at anaphase I showing a chromatid bridge (700×).

ularity in second division, there were evidently some anaphase II bridges and misdivisions, resulting in considerable micronuclei formation. Only about 1 per cent (14 out of 1,457) of the spore quartets were normal, with the remainder appearing much like those of canton. Pollen grains were largely small, empty, and shriveled; only 0.5 to 1.0 per cent of the grains were well-filled.

Pacol. No irregularities were observed in pacol meiosis. The early meiotic stages showed the nucleolus very distinctly, but the chromosomes were again seldom sharply differentiated. At metaphase I the chromosomes assorted regularly at the metaphase plate. Chromosome counts then and at early anaphase showed that pacol had 11 pairs of chromosomes. At telophase I the cell membrane was elaborated normally between the two daughter nuclei. At prophase II the nucleolus of the daughter nuclei was deeply stained and surrounded with chromosome threads and heterochromatin. At metaphase II the dyads of the two nuclei assumed positions at the equators of the newly formed spindles. No chromosome counts were made at this stage. At anaphase II the chromatids of each dyad moved apart to the spindle poles, thus completing meiotic distribution of the chromosomes. At telophase II the four groups of chromosomes reorganized as a quartet of nuclei, each containing one complete genome which was composed of chromosomes from each of the tetrads present in metaphase I.

The resulting pollen grains were very uniform, well-filled with cytoplasm, and round. The different meiotic stages studied clearly indicate that the cytological behavior of pacol is normal and that it is diploid and fertile.

Saba. At early prophase a big nucleolus with chromosome threads appeared. Occasionally, a cell had two nucleoli, one usually bigger than the other. At diakinesis the chromosomes were observed to be irregular, poorly stained and hardly countable. At metaphase I the chromosomes assorted at the metaphase plate with some precocious chromosomes far from the equatorial plate. Chromosome counts made at this stage and at early anaphase showed that saba had 33 chromosomes and is therefore triploid. At anaphase I irregularities typical of other triploid bananas (Wilson, 1946) were observed. The irregular progress of the trivalents from the metaphase plate to the poles resulted in the formation of bridges and laggards. These irregularities persisted into the succeeding stages of microsporogenesis. Laggards were observed at the equatorial plate as late as telophase I, and micronuclei were commonly observed after metaphase II at the former site of metaphase I. Metaphase and anaphase II proceeded regularly in the few cells in which they were observed. Some of the micronuclei were also observed to undergo a second meiotic division. The microspore quartets were highly irregular, being composed of 4 to 10 cells. Pollen grains were nearly 100 per cent sterile, irregular, and empty.

Mitosis

Mitotic studies of the cytological specimens were not successful. Materials were limited and no chromosome counts were made. Staining the root tip smears with either acetocarmine or aceto-orcein was not satisfactory. Other smear techniques which will permit maceration of the cells should be tried.

DISCUSSION

The chromosome counts made on the four abacá varieties do not agree with the n = 12 preliminary count of Umali and Valdez (1951) and the n = 12 count of Cheesman and Larter (1935). It is possible that Cheesman and Larter did not work with *M. textilis* but with *Eumusa* or *Rhodochlamys,* both species having a haploid number of 11 chromosomes (Chandraratna, 1951). According to Chandraratna, abacá belongs to section *Australimusa,* all species of which have a haploid number of 10. Valdez' count was offered as a preliminary finding and was not followed by any confirming report.

The sterile or nearly sterile canton and minay have distinct and different kinds of abnormalities. These aberrations are apparently a result of different fundamental causes.

In both canton and minay all or nearly all of the pollen were empty and extremely shriveled in appearance. Very few of the pollen grains were round or appeared to have normally developed cytoplasm. It has been noted by Yost *et al.* (1953) that pollen irregularities in Datura following thermal neutron bombardment result either in (a) empty, shriveled grains which have been found to be definitely correlated with chromosomal aberrations or in (b) very small grains with more or less degenerated contents correlated with genetic mutations. On this basis, it would follow that the empty shriveled grains which characterize canton and minay would suggest chromosomal aberrations, which would appear at metaphase I and anaphase I as cytological irregularities. This appears to be the case in minay where bridges and fragments were observed, suggestively the result of crossing over within paracentric inversions. In contrast, the first meiotic division of canton was remarkably regular. It thus appears more likely that the sterility of canton is genetically controlled. Grun (1951) noted the absence of a relationship between meiotic irregularity and pollen sterility in alfalfa, the sterility observed being attributed to gene mutation. This may be the case in canton. Chromosome separation in first meiosis proceeded regularly in canton, but irregular cell wall development occurred causing the formation of micro-cells between the two daughter cells. This abnormality in cytoplasmic development continued to the second meiotic division resulting in the formation of irregular spore quartets. Since this abnormality could not be attributed to the chromosomal type of aberration, the most satisfactory explanation now points to a genetic cause.

It is highly probable that canton is a derived hybrid of *M. textilis* and *M. balbisiana* because it possesses characters that are intermediate between the two. According to Cheesman (1949), canton resembles the artificially raised *M. balbisiana* x *M. textilis* hybrids in Trinidad. The cross must have taken place many years ago; then a backcross to *M. textilis* could have occurred, satisfactorily explaining the 10 pairs of chromosomes in canton. If canton were a direct hybrid, it would have $2n = 21$ chromosomes since *M. textilis* has $2n = 20$ and *M. balbisiana* $2n = 22$; further, it would show a high degree of chromosomal irregularity.

The small, empty, shriveled pollen grains of minay are apparently caused by chromosomal aberrations. It is evident that inversions are the most significant of these aberrations and that several of these are present in the chromosome complement of minay. That certain of these inversions are paracentric was evidenced by the presence of chromatid bridges with acentric fragments at anaphase I. The only viable products of meiosis in paracentric inversion of heterozygotes are the chromatids which undergo no crossing over within the inverted sections (Sinnott *et al.*, 1950). This explains why minay produces incidental normal spore quartets. Sharp (1943) also states that the crossing over within the inversion will produce a fairly high degree of sterility among heterozygotes.

The remarkable similarity of minay to canton in botanical characteristics implies that they have the same origin. The chromosome number (n = 10) of minay suggests that it is also a derived hybrid like canton.

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POSSIBLE SOURCES OF RESISTANCE TO ABACÁ MOSAIC AND BUNCHY-TOP [1]

FERNANDO A. BERNARDO and DIOSCORO L. UMALI

Pacol, "Agotay" and *Musa ornata* Roxb. showed complete resistance while canton showed only a high degree of resistance to abacá mosaic. Minay and *Ensete glaucum* Roxb. were infected with the disease but appeared to possess a certain degree of resistance. "Saguing maching," Red and White Alinsanays, twenty-one varieties of abacá, three intervarietal crosses and suckers from nine vigorous clones easily succumbed to the mosaic disease.

Pacol also exhibited complete resistance to bunchy-top disease while canton showed only a high degree of resistance.

The current abacá breeding program in the U.P. College of Agriculture, Guinobatan Abacá Experiment Station, Davao Abacá Experiment Station and Economic Garden at Los Baños, Laguna is designed to produce abacá hybrids resistant to mosaic disease. F_1 hybrids of pacol (*Musa balbisiana* Colla.) and abacá were produced at the College of Agriculture and the Davao Abacá Experiment Station and tests for disease resistance in the former showed that F_1 hybrids are highly resistant to abacá mosaic and bunchy-top (Umali and Bernardo, 1956) although very susceptible to vascular or bacterial wilt (Umali, Ick, and Orillo, 1956).

Crosses between abacá and canton were produced in the College of Agriculture while abacá × *Musa lolodensis* [2] and abacá × minay were reportedly produced in the Davao Abacá Experiment Station and Guinobatan Abacá Experiment Station, respectively. Other than the four hybrids mentioned, no other interspecific crosses were reportedly produced. This is perhaps because pacol, canton, minay and *M. lolodensis* Cheesman are considered by the breeders as the best parental materials for breeding resistance into abacá. Although pacol, canton, and minay admittedly possess desirable agronomic characters (Brewbaker and Umali, 1956), their resistance to abacá mosaic and bunchy-top diseases has not been reported. So far, no

[1] Central Experiment Station Contribution No. 1913. Prepared in the Department of Agronomy, Division of Plant Breeding.

[2] The reported hybrid is suspected to be something entirely different, because samples of Davao's *M. lolodensis* were identified by J. L. Brewbaker as the 22-chromosome saguing maching.

planned experiments have been conducted to determine their resistance to both diseases. On the other hand, both the desirable agronomic characters and the resistance to abacá mosaic of *M. lolodensis* are not yet known.

The reaction to abacá mosaic of the different promising breeding materials which include pacol, canton, minay and agotay was tested in the Division of Plant Breeding. Abacá varieties being grown in Albay, Camarines Sur, Sorsogon, Leyte and Davao and some intervarietal crosses were included in the test.

MATERIALS AND METHODS

The following available plant materials were used:

Musa species:

Pacol, *M. balbisiana* Colla.
Agotay, *M. banksii* F. V. M.
Saguing maching, *M. banksii* F. V. M.
M. ornata Roxb.

Putative hybrids:

Canton, *M. textilis* × *M. balbisiana*
Minay, *M. textilis* × *M. balbisiana*
Red Alinsanay, *M. textilis* × *M. banksii*
White Alinsanay, *M. textilis* × *M. banksii*

Ensete species:

"Virgen" banana, *E. glaucum* (Roxb.) Cheesman

Abacá (*M. textilis* Née):

Twenty-one varieties,[a] one plant each

Intervarietal crosses of *M. textilis:*

Putian × Magsarapong
Putian × Kurisan
Magsarapong × Inisarog
"Experiment Station" [b]

M. ornata and *E. glaucum* were included in the test for mosaic resistance despite the lack of desirable agronomic characters in both plants. No plants of *M. lolodensis* were available for inclusion in the study.

Pacol, canton, saguing maching, *M. ornata* and *E. glaucum* were obtained from the College of Agriculture; agotay and mi-

[a] See table 2.

[b] Vigorous abacá clones labelled as Experiment Station No. 1, 2 or 3 in the old abandoned abacá plantation of the College of Agriculture. The plants are believed to be intervarietal crosses but their origin is not known.

nay, from the Guinobatan Abacá Experiment Station; and Red and White Alinsanays, twelve abacá varieties and three intervarietal crosses, from the Economic Garden.

In all cases of disease transmission, mosaicked and bunchy-topped abacá plants served as sources of inoculum and *Aphis gossypii* Glover and *Pentalonia nigronervosa* Fitch were used as insect vectors for the diseases, respectively. *A. gossypii* were obtained from gumamela flower buds while *P. nigronervosa* were collected from abacá. The aphids were allowed to feed on the source of inoculum for 24 hours and transfers or "inoculations" were accomplished with the aid of the moistened end of a camel's hair brush. Fifty adult aphids were used in each transmission to standardize the "doses" of inoculum. An interval of one week to 1.5 months was allotted between "inoculations" to provide enough time for the incubation period of the virus.

Plants that were not infected after repeated "inoculations" were tested for tolerance to the virus by colonizing nonviruliferous aphids on them and allowing these aphids to feed on healthy abacá seedlings, variety Maguindanao.

RESULTS AND DISCUSSION

Pacol. After the tenth "inoculation" with mosaic virus, the three pacol plants did not show any apparent symptom of the disease. The two plants which were "inoculated" ten times with the bunchy-top virus also remained healthy even after two months. Test for tolerance to either virus did not show any posiitve result, which indicate beyond doubt that pacol is completely resistant if not immune to abacá mosaic and bunchy-top viruses.

Agotay. One of the plants died after the second "inoculation" with mosaic virus, and another after the third. The third and last plant was vigorous and healthy. However, previous "inoculations" on this plant were done with varying number of aphids ranging from 10 to 50 and as frequent as two to six times a week, obviously not allotting enough time for the incubation period of the virus. This faulty procedure was followed because the test for resistance was done prior to the standardization of "doses." The plant did not show any symptom of mosaic infection after the thirty-fifth "inoculation" and tests for tolerance showed negative results.

Although the experimental result was limited to one plant and despite the non-standardized method of "inoculation" it may be con-

cluded that agotay is completely resistant or immune to abacá mosaic.

A test for reaction to bunchy-top was not conducted.

Saguing maching. Of the six experimental plants, four were infected with heart rot disease after the second "dose" of the mosaic virus. The two surviving plants showed mottling symptoms of the disease thirty-eight days after the second "inoculation," which indicate that saguing maching is quite susceptible to the disease (table 1).

TABLE 1.—*Dates and intervals in days of "inoculation" with abacá mosaic virus and dates of "infection"*

EXPERIMENTAL PLANT	NO.	DATE OF "INOCULATION"	INTERVAL BETWEEN "INOCULATIONS" (days)					DATE OF "INFECTION"	LAST "INOC." TO DATE OF "INFECTION" (days)
			1st-2nd	2nd-3rd	3rd-4th	4th-5th	5th-6th		
Saguing maching	1	6-3-55	28					8-8-55	38
Saguing maching	2 [a]	6-3-55	28						
Saguing maching	3 [a]	6-3-55	28						
Saguing maching	4	6-3-55	28					8-8-55	38
Saguing maching	5 [a]	6-3-55	28						
Saguing maching	6 [a]	6-3-55	28						
Musa ornata	1 [b]	10-15-55	19	51	18	20	18		
Musa ornata	2 [b]	10-15-55	90	10	18	20	18		
Canton	1	6-28-55	17	27	24	28		11-10-56	36
Canton	2 [b]	6-28-55	17	27	24	28	43		
Canton	3 [c]	6-28-55	17	27	24	28	43		
Canton	4 [b]	6-28-55	17	27	24	28	43		
Canton	5 [d]	6-28-55	17						
Red Alinsanay	1	4-20-55	7					5-8-55	11
Red Alinsanay	2	6-10-55	10					7-1-55	16
White Alinsanay	1	6-23-55						7-19-55	26
White Alinsanay	2	6-23-55						7-19-55	26
Ensete glaucum	1 [d]	4-28-55	20						
Ensete glaucum	2	4-28-55	20					6-3-55	15
Ensete glaucum	3	4-28-55	20	23	47			7-12-55	14
Ensete glaucum	4	4-28-55	20	23	47			7-15-55	17
Ensete glaucum	5	5-18-55	23	47					
Ensete glaucum	6	5-18-55	23	47				7-22-55	24
Ensete glaucum	7	5-18-55	23	47					

[a] Infected with heart rot disease.
[b] "Inoculated" till the tenth time.
[c] Infected after the ninth inoculation.
[d] Died.

M. ornata. The two experimental plants did not exhibit any apparent symptom of mosaic infection after the tenth "inoculation." Tests for tolerance did not show any positive result indicating that the plants are completely resistant if not immune to mosaic virus (table 1).

A test for reaction to bunchy-top was, however, not attempted.

Canton. The ten suckers were divided into two groups of five and separately "inoculated" with abacá mosaic and bunchy-top. Thirty-six days after the fifth "inoculation," one sucker showed distinct mottling of the young leaves (table 1). One plant died after the first "inoculation." The test was therefore carried further on only three healthy suckers. After the ninth transfer of the insect vector, another plant showed spindle-like chlorotic streaks on the young unfurled leaf.

All the five canton plants tested for resistance to bunchy-top remained vigorous and apparently healthy. However, a close examination of the leaves revealed clearing of the leaf veins in three plants, the most reliable symptom of bunchy-top disease (Ocfemia, 1930).

The presumption that canton is immune to abacá mosaic and bunchy-top (Umali and Valdez, 1951) was not proven in this study. However, it still remains that canton possesses a high degree of resistance to both diseases since it took intensive "inoculations" or repeated transmission of both viruses to incite the diseases on the suckers.

Minay. Like the case of agotay, inoculations on the minay plants were done from two to six times a week with varying number of aphids ranging from 10 to 50. Two plants died after the twenty-first "inoculation" while the two others survived until both were infected with the disease after the twenty-fourth and thrity-second "doses."

The number of "inoculations" that the plant took before it showed mosaic infection cannot, however, be used as an index of the degree of mosaic resistance of minay, as inoculations were done too frequently. It is possible that the mosaic virus had already invaded the inner tissues of the plant in the first few "doses" and yet no symptoms showed early enough while more "inoculations" were made.

One plant showed mosaic symptoms only two months after the first inoculation. Based on this result and the fact that 24 "inoculations" were made within a short time, it may be arbitrarily presumed that minay possesses a considerable degree of resistance to mosaic disease. A repetition of the test using standardized doses at long intervals is however suggested.

Red and White Alinsanays. The two Red Alinsanay plants showed symptoms of mosaic infection after the second "inoculation," while the two White Alinsanay plants exhibited mottling of the leaves after the first "dose." It is however doubted whether a second "dose" was necessary to infect the Red Alinsanay plants, considering the similar number (26) of days from the first "dose" to the time the mosaic symptoms appeared in both types of Alinsanay (table 1).

Ensete glaucum. Of the seven seedlings inoculated with mosaic virus, one died while another showed distinct symptoms of mosaic infection after the second "inoculation." Three other plants exhibited mosaic symptoms after three or four "doses" (table 1). Considering the number of "doses" that the plants took before showing symptoms of infection, it may be concluded that *E. glaucum* has a certain degree of resistance to abacá mosaic.

Abacá varieties. One sucker each of twenty-one different abacá varieties were infected with abacá mosaic after the first or second "dose." The number of days from the last "dose" to the time the first symptoms of infection appeared differed among the abacá varieties tested (table 2). This is perhaps due to the differences in the size and age of the experimental plants. The results indicate that there is hardly any variation in the degree of susceptibility among the different abacá varieties.

It was presumed that the plants were also susceptible to bunchy-top disease since the bunchy-top virus is considered more virulent than the mosaic virus.

Intervarietal crosses. Putian × Magsarapong, Putian × Kurisan and Magsarapong × Inisarog showed mosaic infection after the first "inoculation." Of twelve suckers obtained from different "Experiment Station" clones nine showed symptoms of infections after the second inoculation while three died.

TABLE 2.—*Abacá varieties and crosses: dates of "inoculation" and "infection" with abacá mosaic disease*

VARIETY	DATE OF 1ST "INOCULATION"	DAYS BET. 1ST & 2ND "INOCULATIONS"	DATE OF "INFECTION"	LAST "INOC." TO DATE OF "INFECTION" (days)	VARIETY OR CROSS	DATE OF 1ST "INOCULATION"	DAYS BET. 1ST & 2ND "INOCULATIONS"	DATE OF "INFECTION"	LAST "INOC." TO DATE OF "INFECTION" (days)
Laguis	6- 3-55	13	7- 2-55	16	Linawaan	6-24-55	—	7-16-55	22
Lausigon	6- 3-55	—	6-10-55	7	Samorong Pula	6-24-55	26	7-30-55	8
Binukid	6-14-55	—	7- 7-55	21	Magsarapong	6-24-55	—	7-20-55	26
Bongolanon	6-10-55	5	7- 1-55	16	Pula	6-28-55	—	7-17-55	19
Bulao	6-14-55	18	7-25-55	23	Alman	6-28-55	—	7-20-55	22
Itom	6-14-55	—	7- 2-55	18	Putian × Magsarapong	6-23-55	—	7- 2-55	9
Binagacay	6-14-55	—	6-24-55	10	Putian × Kurisan	6-23-55	—	6-30-55	7
Puti	6-16-55	—	7-12-55	26	Magsarapong × Inisarog	6-30-55	8	7-17-55	9
Tinawagang Puti	6-21-55	11	7-25-55	23	"Expt. Sta." Clone 34	6-10-55	5	7-12-55	27
Layahon	6-21-55	11	7-25-55	23	"Expt. Sta." Clone 37	6-10-55	5	7- 1-55	16
Libutanay	6-21-55	11	7-25-55	23	"Expt. Sta." Clone 40	6-10-55	5	7- 2-55	17
Samina	6-21-55	—	7- 2-55	11	"Expt. Sta." Clone 30	6-13-55	26	7-29-55	30
Inosa	6-21-55	11	7-25-55	23	"Expt. Sta." Clone 41	6-13-55	26	7-29-55	30
Maguindanao	6-21-55	14	7-25-55	20	"Expt. Sta." Clone 31	6-13-55	26	7-28-55	29
Sinamoro	6-21-55	14	7-25-55	20	"Expt. Sta." Clone 44	6-13-55	26	7-18-55	19
Kurisan	6-24-55	—	7-17-55	23	"Expt. Sta." Clone 48	6-13-55	26	7-30-55	31

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TRANSMISSION OF VIRUSES FROM DIFFERENT PLANTS TO ABACÁ (*MUSA TEXTILIS* NEE)[1]

M. S. Celino and Aureo L. Martinez [2]

WITH THREE PLATES

Mosaics of *Rottboellia exaltata* L., *Digitaria sanguinalis* (L.) Scop., *Echinochloa colonum* (L.) Link, and *Panicum distachyum* L. which are transferable to abacá directly or through corn and which produce mild mosaic patterns are different from the intense mottling of abacá and *Canna indica* mosaics. Inoculation of abacá with viruses from naturally occurring mosaic of corn, sugar cane, cogon (*Imperata cylindrica* [L.] Beauv.), *Paspalum conjugatum* Berg., garlic, tobacco, *Vigna sinensis* and cucurbit did not result in symptoms.

Corn and a number of grass weeds are hosts of abacá mosaic and also of the aphids that transmit it. In mosaic-infected abacá plantation weeds, particularly grasses, can be infected by the virus. From these infected plants the aphids spread the disease with the same degree of virulence to nearby abacá plants.

Grass mosaics, caused by viruses or strains of virus that are probably not related to abacá mosaic virus, are not as destructive to abacá as the latter, but their presence in abacá together with abacá mosaic virus could result in a mosaic complex. Formation of a mosaic complex in abacá will render the problem of disease control more difficult.

A mosaic naturally occurring in arrowroot produces in abacá a leaf mottling which varies in intensity from mild to severe. Arrowroot mosaic also causes slight to severe stunting effect in young abacá plants.

Report of the transmission of abacá mosaic virus to abacá, *Canna indica* and corn by four species of aphids (*Aphis gossypii* Glover, *A. maidis* Fitch, *Rhopalosiphum nymphaeae* (L.) and *R. prunifoliae* Fitch) and the subsequent studies which showed the susceptibility of abacá plant to the mosaic virus of *Canna indica* stimulated investigation on the transmission to abacá of viruses from different sources. Results obtained from these studies by earlier workers are briefly reviewed in table 1. It appears that of the plant viruses tested on abacá those of the graminicolous species like corn (Lawas and Fernandez, 1949), *Echinochloa colonum* (L.) Link reported by

[1] Central Experiment Station Contribution No. 1914.

[2] The writers thank Dr. F. T. Orillo, head of the Department of Plant Pathology, Dr. G. O. Ocfemia, professor of plant pathology, and Dr. C. S. Reddy, visiting Cornell professor, for reading the manuscript.

TABLE 1.—*Transmission to abacá of viruses from different plants*

INVESTIGATOR	*Musa textilis*	*Canna indica*	*Maranta arundinacea*	*Saccharum officinarum*	*Zea mays*	*Paspalum conjugatum*	*Panicum* sp.	*Echinochloa colonum*	*Digitaria sanguinalea*	*Rottboellia exaltata*	*Panicum distachyum*	*Imperata cylindrica*	*Vigna sinensis*	*Cucumis sativus*	*Nicotiana tabacum*	A seedy *Musa* sp.	Banana (unidentified)	*Elephantopus mollis*	*Stachytarpheta jamaicensis*	*Hippeastrum* sp.	Ornamental *Canna* (unidentified)	*Capsicum annum*	*Brassica pekinensis*	*Brassica juncea*	*Raphanus sativus*	*Momordica charantia*	*Allium sativum*
Ocfemia and Celino, 1938, 1941	+	+																								
Ocfemia, Macaspac, and Hsieh, 1941	+	+																								
Lawas and Fernandez, 1949					+											+										
Juliano, 1951	+	—	—	—	—	—	—										—				—					
Protacio, 1953		—			—	(+)		[+]				—	+						—							
Castillo, 1953			+					+								+										
Legaspi, 1955	+					—			—	—																
Escober, 1956					—	—	—		+	+	+	—	—	—									—	—	—	—
The writers	+	+	+		—	—	—	+	+	+	+	—	—	—	—		—				—						—

— = No infection on abacá.
+ = Infection induced in abacá.
(+) = Virus infected abacá after its passage through *Canna indica*.
[+] = Virus infected abacá after its passage through corn.

Castillo,[3] *Digitaria sanguinalis* (L.) Scop., *Rottboellia exaltata* L. and *Panicum distachyum* L. reported by Escober [4] induced mild mosaic infection in abacá. But viruses of mosaics of other grasses such as *Saccharum officinarum* L., *Paspalum conjugatum* Berg., *Panicum* species and *Imperata cylindrica* (L.) Beauv. failed to infect abacá directly (Juliano, 1951; Protacio [5] and Legaspi [6]). Protacio, however, reported infection of abacá with virus from *Paspalum conjugatum* after its passage through *Canna indica* and of *Digitaria sanguinalis* mosaic virus passed through corn.

Positive transmission to abacá of viruses from *Vigna sinensis* (Leguminosae), *Maranta arundinacea* (Marantaceae) collected in Davao, Mindanao and a seedy *Musa* species (Musacaea) was obtained. But no infections were obtained by viruses from a cultivated Philippine banana, *Hippeastrum* species (Amaryllidaceae), ornamental *Canna* (Cannaceae), *Stachytarpheta jamaicensis* (L.) Vahl. (Verbenaceae), *Elephantopus mollis* H.B.K. (Compositae), pepper (*Capsicum annum* L., Solanaceae), *Momordica charantia* L. (Cucurbitaceae), radish (*Raphanus sativus* L.), mustard (*Brassica juncea* S-VII.) and pet-sai (*Brassica pekinensis* [Lour.] Rupr.) of the family Cruciferae.

This investigation was prompted to (a) study further the transmission of mosaics of different plants to abacá, (b) determine how destructive they are and (c) find out what relation they have to the infectious and naturally occurring mosaics of abacá and *Canna indica* in Mindanao.

MATERIALS AND METHODS

Different species of plants infected with mosaic were collected from time to time in the Central Experiment Station, College of Agriculture; Los Baños Economic Garden, Bureau of Plant Industry;

[3] Bernardo S. Castillo. Chart of hosts and vectors of abacá mosaic. Exhibit at Abacá Mosaic Control School, Davao City, September 8-11, 1953.

[4] Jaime T. Escober. Transmission of grass mosaics to abacá and the influence of the source of inoculum on mosaic patterns. (Thesis presented for graduation with the degree of Bachelor of Science in Agriculture from the College of Agriculture, 1956. Unpublished.)

[5] Domingo B. Protacio. The relation of the mosaic of some weeds and other plants to abacá mosaic. (Thesis presented for graduation with the degree of Bachelor of Science in Agriculture from the College of Agriculture, 1953. Unpublished.)

[6] Benjamin M. Legaspi. The relation of the mosaic viruses of garden crops and weeds to abacá. (Thesis presented for graduation with the degree of Bachelor of Science in Agriculture from the College of Agriculture, 1955. Unpublished.)

Lipa, Batangas; San Pablo City; and in Guinobatan, Albay where mosaic of abacá does not occur.

The plant collections were grown in the greenhouse of the Department of Plant Pathology and were used later as sources of virus in aphid transmission experiments.

TRANSMISSION OF VIRUSES OF GRASS MOSAICS TO ABACA SEEDLINGS

(a) *Transmission of mosaic of aguiñgay* (*Rottboellia exaltata* L.) *to abacá.* On January 6, 1955, six abacá seedlings were used in transmission tests by transferring to each seedling a batch of 50 individuals of *A. maidis* from mosaic-infected *R. exaltata* (Plate 1, fig. 3). Six abacá seedlings with *A. maidis* from healthy grass served as control. The aphids were allowed to stay on the abacá plants for 48 to 72 hours, after which they were destroyed by a spray of dilute nicotine sulfate solution. After allowing sufficient time for observation in the greenhouse, four abacá plants developed light mosaic symptoms after 18, 26, 28, and 35 days.

In February, 1955, 10 abacá plants were exposed to infective individuals of *A. gossypii* which were reared overnight on *R. exaltata* with mosaic. Of this number seven developed mild mottling on newly expanded leaves.

Inoculation of four young abacá seedlings on April 4 with *A. maidis* as carrier of virus from the same source and four other seedlings on April 5, 1956, with *A. gossypii* as vector resulted likewise in mild symptoms in 15 to 18 days.

The symptoms induced by *R. exaltata* mosaic virus in abacá seedlings start with the appearance of a few lightly colored, narrow, spindle-shaped patches on partly emerged or on newly unfurled leaves. These spindle-shaped patches are scattered in the leaf lamina and lie in the direction of the veins. They have well defined outline and vary in size from 1 by 10 mm. to 3 by 36 millimeters. As infection progresses more discolored patches appear on new leaves to form a mosaic pattern or mottling (Plate 1, fig. 4). Mottling is clearly discernible on young leaves. It gradually fades out, however, and changes into a dull yellowish-green in mature and old leaves. Not infrequently fusion of discolored patches that were formed close to each other takes place.

Later, the symptoms of the disease appear also on leaves of suckers or "peepers" of artificially infected abacá plants. But as in the mother plant mottling is also of the mild type.

When such artificially infected abacá plants were planted in the open they also consistently showed mild mosaic pattern. In fast growing plants the symptoms appeared off and on. Complete masking of symptoms, however, was not observed. These symptoms differ markedly from the brilliant and severe mottling induced in abacá by virus from either mosaic-infected abacá or *Canna indica* from Davao, Mindanao (Calirisan, 1939; Ocfemia, 1937; Ocfemia and Celino, 1938; Celino, 1940). Although mosaic of *Rottboellia exaltata* infects abacá it does not seem to be destructive to this plant.

Mosaic of *R. exaltata* infects corn seedlings readily. It has been found experimentally that passage of *R. exaltata* mosaic virus through corn did not increase its virulence. The virus that *A. maidis* recovered from artificially infected corn plants produced also a mild mosaic pattern in abacá seedlings in retransmission experiments.

Abacá plants infected with mosaic of *R. exaltata* showed no indication of immunity or resistance against abacá mosaic virus. Such plants were readily infected by abacá mosaic in artificial infection experiments. They developed intense mottling similar to those described on mosaic of abacá, *C. indica,* and arrowroot.

Healthy *R. exaltata* seedlings are susceptible to abacá mosaic. Young seedlings grown from seeds of healthy *R. exaltata* when artificially inoculated in the greenhouse with virus of abaca mosaic readily developed mosaic disease in two to three weeks. From such plants the virus was recovered by *A. gossypii* and *A. maidis* and when retransmitted to abacá it infected abacá seedlings and produced severe mottling. Evidently, passage of abacá mosaic virus through *R. exaltata* did not reduce its ability to produce severe symptoms. *Rottbocllia exaltata,* a widely-occurring grass in the Philippines, can serve as secondary host to abacá mosaic in plantations where the disease is present.

(b) *Transmission of the mosaic virus of Digitaria sanguinalis* (L) *Scop. to abacá.* Following the method used in transmitting the mosaic virus of *R. exaltata,* inoculation of eight abacá seedlings on January 26 and 27, 1955, with virus transferred directly from mosaic-infected *D. sanguinalis* resulted in mild symptoms in two plants after 26 and 29 days (Plate 1, fig. 1). Four other abacá seedlings inoculated on March 16, 1955, likewise produced infection in one

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Fig. 1.—Portions of crabgrass leaves *Digitaria sanguinalis* (L.) Scop., showing mottling due to mosaic infection. Collected in the College of Agriculture campus, College, Laguna.

Fig. 2.—A leaf of a young abaca plant with a mild mosaic pattern caused by artificial inoculation with virus of *Digitaria sanguinalis* mosaic.

Fig. 3.—Portions of aguiñgay leaves, *Rottboellia exaltata* L., naturally infected with mosaic. Collected in Los Baños Economic Garden, Los Baños, Laguna.

Fig. 4.—A close-up of a leaf of a young abacá plant showing symptoms of mosaic infection caused by a strain of virus from mosaic-infected *Rottboellia exaltata*. (*Photographed by the Photographic Division, College of Agriculture*).

plant after 28 days. Of 22 abacá seedlings inoculated in insect transmission experiments from March 4 to 22, 1955, with *D. sanguinalis* mosaic virus passed through corn, five plants developed light mosaic pattern on the leaves in 28 to 34 days.

It has been observed that abacá plants infected by virus either from mosaic-infected *D. sanguinalis* or from corn plants artificially inoculated with mosaic of *D. sanguinalis* developed a mild mosaic infection. The general appearance of the symptoms formed on abacá leaves are more or less similar to those induced by *R. exaltata* mosaic virus. Few light yellowish spindle-shaped patches that vary in size from 1 by 6 mm. to 3 by 40 mm. appear on the lamina of unfolding leaves of abacá seedlings three to four weeks after inoculation (Plate 1, fig. 2). As only few widely separated discolored patches are formed on abacá leaves mottling appears to be very mild in the early stages of the disease. As infection progresses the symptoms may increase slightly in intensity but usually do not develop beyond the mild stage. The symptoms decrease in intensity as the abacá plants advance in growth. It appears that the disease does not impair the growth of abacá plants to any marked degree. Temporary masking of symptoms by infected abacá plants planted in the open is not uncommon. The symptoms, however, reappear on subsequent leaves or on leaves of suckers that are produced later by artificially inoculated plants. The first three or four leaves of young suckers usually come out with intense mottling but as growth of the suckers progresses mild mosaic symptoms develop on the subsequent leaves (Plate 2, fig. 1).

Healthy *D. sanguinalis* plants when inoculated with abacá mosaic virus showed mosaic disease in two weeks. From these plants the virus was recovered by *A. maidis* and when introduced into young abacá seedlings it induced mosaic with formation of brilliant mottling. Unlike those infected with grass mosaic these abacá plants did not show masking of the disease. On the contrary the symptoms of the disease increase in intensity as the abacá plants advance in growth. It appears probable that in a field where mosaic of abacá is present *Digitaria sanguinalis* can harbor abacá mosaic virus and from this plant the virus can be communicated back to abacá in unaltered virulence.

(c) *Transmission of Panicum distachyum mosaic virus to abacá.* Aphid transmission experiments of the mosaic virus of *P. distachyum* on March 8 and on May 5, 1955, resulted in infection of six

out of 15 abacá seedlings (Plate 2, fig. 2). The incubation period ranged from 31 to 38 days. Eight corn seedlings which were inoculated as indicator plants readily showed mosaic in six of them in 6 to 9 days.

On December 11, 1955, eight abacá seedlings were used in insect transmission experiments of *P. distachyum* mosaic virus passed through corn. Fifty individuals of *A. maidis* were transferred from artificially infected corn to each abacá. After about a month or more in the greenhouse four abacá plants showed mild mosaic pattern with respective incubation periods of 28, 30, 32, and 35 days.

The symptoms produced in abacá seedlings by *P. distachyum* mosaic virus vary from almost needle-like, pale white streaks to narrow spindle-shaped pale yellowish patches which lie parallel to the veins of the leaves. These symptoms are clearly discernible on unfolding and on newly expanded abacá leaves. They are practically similar to the symptoms formed by *Rottboellia* and *Digitaria* mosaic viruses. As the leaves of infected abacá plants advance in age these fine yellowish streaks fade out and diffuse into the surrounding green tissues.

Mosaic of *Panicum distachyum* causes only a mild mosaic infection in young abacá seedlings. In fast growing abacá plants the mosaic pattern weakens and it may appear off and on on subsequent leaves.

Abacá plants artificially infected with virus of *P. distachyum* mosaic were readily infected when inoculated with the virus of mosaic of abacá. This result would indicate that the presence of *P. distachyum* mosaic virus in abacá does not protect the plant from infection with the severe form of abacá mosaic.

From *P. distachyum* artificially infected with severe form of abacá mosaic the virus was transferred back to abacá seedlings and induced a mosaic infection with intense mottling. This grass, therefore, like the other grasses, can serve as a secondary host plant of abacá mosaic virus. Kent (1954) points out that weeds, particularly grasses, serve as breeding places for aphids. As soon as the weeds are cut or their growth slows down because of maturity, drought, etc., the aphids move to the abacá.

(d) *Transmission of the virus of mosaic of Echinochloa colonum* (L.) *Link to abacá.* With *A. maidis* as vector, virus of *Echinochloa colonum* mosaic collected in Los Baños, Laguna, was transferred to eight abacá seedlings on February 3, 1955. Fifty aphids

from the mosaic-infected grass were transferred to each of the abacá seedlings. Eight corn seedlings were inoculated along with the abacá plants as indicators. Four abacá seedlings served as control. In this test two of the inoculated abacá plants showed a few pale white streaks on newly opened leaves three weeks after inoculation. These fine streaks, however, were noted only on three succeeding leaves after which they did not appear any more on subsequent leaves. No similar development was noted on the control plants. All indicator corn plants, however, showed mosaic in 4 to 7 days.

Five abacá plants inoculated similarly on February 4, 1955, showed light streaking in one plant but such streaks were observed only on two succeeding leaves. These streaks as well as those obtained on abacá plants in the preceding test did not in any way resemble the mild mosaic pattern induced by mosaic of *R. exaltata, D. sanguinalis,* and *P. distachyum* on abacá leaves. Six other abacá plants used later in insect transmission test of *E. colonum* mosaic virus with *A. maidis* as vector did not result in infection.

With mosaic of *E. colonum* from Lipa, Batangas, as the source of virus, ten abacá seedlings were exposed to infective *A. maidis* on October 3 and 14, 1955. Twelve other seedlings were exposed to viruliferous *A. gossypii* on October 20 and 22, 1955. These inoculations of abacá with either *A. maidis* or *A. gossypii* as vector of *E. colonum* mosaic virus did not result in disease. All corn plants inoculated as indicators, however, showed mosaic in two weeks.

In insect transmission tests in the summer of 1956 the virus from diseased *E. colonum* collected on the College campus induced a mild mosaic pattern in young abacá seedlings. Retransmission of the disease to healthy *E. colonum* resulted in mosaic which when transmitted back to healthy abacá seedlings induced again mild mosaic symptoms.

Different results, however, appeared when *E. colonum* artificially infected with severe abacá mosaic was used as source of virus. Mosaic infection characterized by intense mottling was obtained in 10 to 25 days on four abacá plants that were exposed to virus-laden *A. gossypii* on April 19 and on four other abacá and three arrowroot plants similarly treated on April 21, 1956 (Plate 2, fig. 3). These results tend to show that the virulence of abacá mosaic virus is not altered by its passage through *E. colonum.* According to Castillo[7] *E. colonum* is a primary source of abacá mosaic in Davao. This

[7] Castillo, *op. cit.*

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Fig. 1.—A mild mosaic pattern shown by an abacá plant, one year after it had been infected with virus of *Digitaria sanguinalis* mosaic.

Fig. 2.—A leaf of a young abacá plant with mild mosaic pattern induced by virus of *Panicum distachyum* mosaic.

Fig. 3.—An intense mosaic pattern produced by the abacá mosaic virus in an abacá leaf after its passage through the grass, *Echinochloa colonum* L. (*Photographed by the Photographic Division, College of Agriculture.*)

is likely as *E. colonum* could be infected by abacá mosaic virus in abacá plantations where this disease is rampant.

(e) *Failure of transmission of mosaic of cogon (Imperata cylindrica* (L.) *Beauv. = Imperata exaltata Brongn.) to abacá.* Exposure of four abacá seedlings on March 10, 1955, to feeding of *A. maidis* from cogon infected with mosaic did not result in infection. A similar experiment performed on March 15, 1955, which involved six abacá seedlings also yielded negative results. Of eight abacá seedlings inoculated on March 25, 1955, with *A. gossypii* as vector none of the plants developed mosaic even after several months.

(f) *Failure of transmission of corn mosaic to abacá.* With mosaic of corn collected in Los Baños, Laguna, as source of virus, transmission experiments were performed from January to March, 1955. Four abacá seedlings were exposed to *A. maidis* from corn on January 28, two on February 1, four on February 10, two on February 12, and six on March 3, 1955. Eight corn seedlings were inoculated as indicators. In these tests mosaic infection was obtained in all corn plants with incubation periods of 7 to 13 days. All experimental abacá plants, however, appeared healthy as the control plants.

In a separate trial corn seedlings artificially infected with corn mosaic originally collected in the Experiment Station of the College of Agriculture were planted with six healthy abacá plants in a large wooden box outside the greenhouse. As the corn plants advanced in growth grass aphids, particularly *A. maidis,* colonized and multiplied profusely on the flowers, leafsheaths, and on the base of the leaves. From the mosaic-infected corn plants the aphids were allowed to move to the abacá plants at will. In addition, a large number of aphids were actually transferred from time to time from corn to partially emerged leaves of the experimental abacá plants. In spite of repeated exposures of the abacá plants to viruliferous corn aphids these plants did not exhibit any symptom of mosaic infection even after one year. In contrast, the indicator corn seedlings which were inoculated by transferring to each seedling 25 infective aphids showed mosaic infection in one to two weeks.

In another wooden box a similar planting of healthy abacá and corn plants artificially infected with abacá mosaic was prepared. As in the preceding test corn aphids were allowed to colonize on the corn plants. From corn the aphids moved later to abacá plants at

will. Actual transfers of aphids from corn infected with mosaic to abacá were also made. In this test the abacá plants became infected. They showed 100 per cent mosaic disease in two to three months.

From May 5 to 20, 1956, three young corn plants naturally infected with mosaic in Los Baños, Laguna, were used as virus source in infection experiments. *Aphis gossypii* were colonized on these plants overnight after which the aphids were allowed to move at will to experimental abacá and corn seedlings. The abacá seedlings were exposed five times to cultures of aphids; the indicator corn seedlings, two times. But in spite of repeated exposures of the abacá seedlings to viruliferous aphids mosaic disease did not appear on any of them. One hundred per cent of the indicator corn seedlings, however, showed mosaic infection.

From May 30 to June 23, 1956, another collection of corn mosaic was used as virus source in another set of transmission experiments. Again the abacá seedlings were exposed to infective *A. gossypii* five times and the corn seedlings, two times.

These two inoculation tests did not result in mosaic symptoms in any of the abacá plants though all of the corn plants became infected.

On July 3, 1956, six abacá seedlings and six corn plants were inoculated by transferring to each abacá 50 aphids and to each corn seedling 25 individuals of *Aphis maidis* reared previously on corn plants infected with mosaic. On July 6 four other abacá seedlings and four corn plants were similarly exposed to infective *A. maidis* in the greenhouse. But as in the above experiments only the corn plants showed mosaic infection. The abacá seedlings appeared healthy when the experiments were concluded. In separate inoculation tests corn mosaic likewise failed to infect arrowroot and *Canna indica* seedlings.

These results are of interest as it has been generally believed that corn mosaic is a primary source of abacá mosaic. But although corn mosaic virus is not infectious to abacá, corn is susceptible to abacá mosaic virus (Celino and Ocfemia, 1941). Corn can harbor abacá mosaic and from this plant *Aphis maidis* and other species of aphids on grasses and other weeds can readily retransmit the virus to abacá without change in virulence. Reinking [8] points out that at-

[8] O. A. Reinking, "Review of Abacá Mosaic Control Program in the Philippines, 1954-1955". United States of America Operation Mission to the Philippines, Agricultural Division, Manila, February, 1955, 34 pp.

tempts to control abacá mosaic in Kidapawan and other abacá areas in Mindanao failed because corn was universally planted with abacá by most small farmers. Moreover, corn is susceptible to infection by different strains of grass mosaic. From corn these mosaics could infect abacá. Infection of abacá plants with these mosaics and with the severe form of abacá mosaic will result in a mosaic complex. This will render the problem of mosaic control more difficult.

(g) *Failure of transmission of sugar cane mosaic to abacá.* The virus of sugar cane mosaic failed to infect abacá seedlings in transmission experiments on May 4, 5, and 8, 1956. *Aphis gossypii* and *A. maidis* were used separately as vectors.

According to Costa and Penteado (1951) corn seedlings are susceptible test plants for the sugar cane mosaic virus. On June 28, 1956, sugar cane mosaic virus was transmitted mechanically to corn seedlings with the aid of carborundum 320. Seven out of 12 corn seedlings treated with virus-laden sap became diseased. From these infected corn plants repeated trials were made to communicate the virus to abacá with *A. gossypii* and the corn aphid, *A. maidis*, as vectors but infection was not obtained on any of the abacá plants. Evidently, passage of sugar cane mosaic virus through corn did not render it infective to abacá.

(h) *Failure of transmission of mosaic of Paspalum conjugatum Berg. to abacá.* Culape plants (*Paspalum conjugatum*) with mosaic collected in San Pablo City and in Los Baños, Laguna, were used as source of virus in aphid transmission experiments. Eight abacá seedlings were exposed to *A. maidis* from *P. conjugatum* with mosaic in December, 1954, and twenty-five others in January and November, 1955. In February, 1956, six young *Canna indica* seedlings grown from seeds were similarly exposed but to *A. gosypii* fed overnight on culape with mosaic. Corn seedlings were inoculated as indicators. In these tests only the corn plants became infected. Both the abacá and *C. indica* seedlings appeared healthy at the end of the experiments.

In subsequent experiments abacá seedlings were inoculated by transferring the *P. conjugatum* mosaic virus from artificially infected corn plants. But even after repeated exposures of abacá seedlings to *A. gossypii* fed previously on corn with mosaic, infection was not induced in any of the check plants.

(i) *Transmission of grass mosaic to arrowroot (Maranta arundinacea).* As arrowroot is susceptible to abacá mosaic, experiments

were conducted to infect arrowroot with grass mosaics. The results obtained showed that with *Aphis gossypii* as vector, viruses from diseased *Rottboellia exaltata* and *Digitaria sanguinalis* could independently of each other infect arrowroot seedlings and induce in these plants a mild form of leaf mottling. This mosaic pattern is plainly evident on young unfurling leaves. These symptoms, however, fade out gradually and they become almost indistinguishable on fully expanded and mature leaves. Not infrequently, infected arrowroot plants mask the symptoms of the disease in eight to 10 weeks. The symptoms however reappear on the suckers but in a very mild degree and they soon fade out after the leaves have attained full development.

In contrast, abacá mosaic virus produces on arrowroot intense or brilliant mosaic pattern. These symptoms develop with increasing intensity as the infected arrowroot plants advance in growth. Later, the suckers of these plants likewise show pronounced mottling. Masking of symptoms either by the originally infected plants or their suckers has not been observed in this case.

(j) *Failure of grass mosaic to infect Canna indica.* Wild *Canna indica* is one of the host plants of abacá mosaic in Mindanao It has been shown previously that *C. indica* mosaic which occurs in Davao could also infect abacá with production of severe mosaic pattern (Ocfemia, Macaspac and Hsieh, 1941). In the present study, however, inoculation of young *C. indica* seedlings with viruses of mosaic of *Rottboellia exaltata* and *Digitaria sanguinalis* did not result in infection. This failure of grass mosaics of non-abacá areas to infect *C. indica,* a plant which is highly susceptible to abacá mosaic, seems to provide an additional evidence that the grass mosaics are not related to abacá and *Canna indica* mosaics in Mindanao.

TRANSMISSION OF VIRUS FROM NON-GRASSES TO ABACÁ SEEDLINGS

(a) *Transmission of mosaic of arrowroot (Maranta arundinacea) to abacá.* With *Aphis gossypii* as vector 14 abacá seedlings were inoculated on July 5 and 7, 1956. Fifty aphids from arrowroot infected with mosaic were transferred to each of the experimental abacá seedlings (Plate 3, fig. 1). An equal number of aphids from healthy arrowroot plants were colonized on each of ten abacá seedlings which served as control. Under conditions in the greenhouse 12 out of 14 experimental abacá plants showed mosaic patterns on the newly formed leaves after 10 to 34 days. Mosaic did not develop on

any of the check plants. The virus was readily recovered from the artificially infected abacá plants. In retransmission experiments seven out of eight arrowroot seedlings used as suscepts developed mosaic disease.

Arrowroot mosaic virus induces mild leaf mottling in abacá (Plate 3, fig. 2). Occasionally, however, an infected abacá plant may send out a leaf with intense mosaic pattern. Expanded leaves of infected abacá plants appear dull, pale green with uneven surface and a wavy margin. The disease generally causes a slight stunting effect in young abacá plants but occasionally severe stunting develops.

(b) *Failure of transmission of garlic mosaic to abacá.* Insect transmission of garlic mosaic virus to young abacá seedlings resulted in slight streaking of little significance. Few scattered, and disconnected dashes, narrow and yellowish to yellowish white were noted on leaves of abacá seedlings three to four weeks after inoculation. Retransmission of the virus to healthy garlic seedlings, however, yielded negative results.

(c) *Failure of transmission of mosaics of cucurbit (Cucumis sativus), cowpea (Vigna sinensis) and tobacco (Nicotiana tabacum) to abacá.* Repeated inoculation of cucumber mosaic virus to abacá seedlings in August, 1955 and in April, 1956 using *Aphis gossypii* as carrier did not result in infection. From April to May, 1956, twenty-five abacá seedlings were used in insect transmission of cowpea mosaic virus but negative results were obtained. Likewise tobacco aphids failed to transmit tobacco mosaic virus to young abacá seedlings. Of eight abacá seedlings inoculated on September 3 and 8, and ten other seedlings on September 15, 1956, not one developed mosaic disease.

DISCUSSION OF RESULTS

With *Aphis gossypii* Glover and *A. maidis* Fitch as vectors, mosaic of *Rottboellia exaltata* L., *Digitaria sanguinalis* (L.) Scop., *Echinochloa colonum* (L.) Link (syn. *Panicum colonum* L.), and *Panicum distachyum* L. was transmitted to young abacá seedlings with mild or weak mosaic patterns. On the contrary inoculation of abacá plants with mosaic of sugar cane, culape (*Paspalum conjugatum* Berg.), cogon (*Imperata exaltata* Brongn.), and corn did not result in symptoms. Lawas and Fernandez reported successful transfer of corn mosaic virus to abacá. It seems that in the studies of Lawas and Fernandez and in ours different strains of grass mosaic virus were involved. This is highly probable as corn is subject to infec-

CELINO AND MARTINEZ: Transmission of Viruses from Different Plants to Abacá

Fig. 1.—A leaf of an arrowroot plant showing symptoms of mosaic disease. Collected in Guinobatan, Albay.
Fig. 2.—A leaf of an abacá plant with mosaic symptoms induced by arrowroot mosaic virus in artificial infection test. Arrowroot mosaic virus produces in abacá a wild mosaic pattern. Occasionally, however, an infected abacá plant may form leaves with brilliant mottling. (*Photographed by the Photographic Division, College of Agriculture*).

tion by corn mosaic virus and a number of other strains of grass mosaic besides. The transmission of *Vigna sinensis* mosaic virus and of *Paspalum conjugatum* mosaic to abacá by way of corn and *Canna indica* as reported by Protacio [9] was not confirmed in this study.

Castillo's finding that *Panicum colonum* L. is a primary source of abacá mosaic in Davao can be explained in the light of our results. It has been invariably shown in this study that this grass is susceptible to abacá mosaic and from it the virus could be transferred back to abacá without any change in virulence. In Davao where abacá mosaic is wide spread and aphid vectors exist in large number in many plantations, infection of *Panicum colonum* with abacá mosaic and subsequent retransmission of the virus from this grass to nearby abacá plants are to be expected. However, in experiments where the virus from *Echinochloa colonum* (syn. *Panicum colonum*) was obtained in non-abacá areas only a mild mosaic disease could be produced in abacá.

The symptoms induced by grass mosaics in abacá remain consistently mild in contrast to the intense mottling of abacá and *Canna indica* mosaics. Owing to such marked differences in symptoms and on the ultimate effect of the particular viruses on the growth of the abacá plants, grass mosaics are to be regarded distinct from abacá and *Canna indica* mosaics.

Grasses should be kept down or checked in abacá areas where mosaic disease is present for they serve either as hosts of abacá mosaic virus or of the aphids that spread it. Furthermore, grasses have also their own mosaic troubles, some of which are transmissible to abacá. In poorly kept plantations, abacá plants are subject to more infection from the grass and abacá mosaics. From the standpoint of disease control a mosaic complex of mixed mosaic infections is far more destructive to abacá and presumably harder to control than a single virus infection.

Except for *Canna indica* mosaic virus reported previously, only that of arrowroot mosaic out of eight viruses studied from nongrasses, produced mosaic infection in abacá (table 1). Infection of abacá with arrowroot mosaic resulted in leaf mottling which varied in intensity from mild to severe at times. Moreover, the leaves formed later by infected abacá plants developed dull green color, uneven surface and wavy margins. Slight stunting effect was noted but in three out of 12 infected abacá plants severe stunting developed.

[9] Protacio, *op. cit.*

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THE RELATION BETWEEN MOSAIC RESISTANCE AND SOME BIOCHEMICAL PROPERTIES OF THE PLANT SAP OF ABACÁ AND ITS RELATIVES [1]

VIRGILIO R. CARAÑGAL and APOLINARIO R. CARAÑGAL, JR.

WITH FOUR TEXT FIGURES

The pH of the aqueous extracts of the leaves and the color reactions for tannins or polyphenols can not be used as diagnostic tests for resistance to abacá mosaic virus. However, preliminary experiments showed that mosaicked abacá plants appeared to have lower pH and more polyphenols than healthy plants.

The biological method of testing for resistance to abacá mosaic is tedious and time-consuming, especially if the reactions of thousands of seedlings to mosaic are to be determined. Since viruses are nucleoproteins, a biochemical approach may be more advantageous. Some simple diagnostic tests for detecting virus infection, like the Lindner's test and the propanol turbidometric method, have been tried with other plants. Catalase activity and pH of the plant sap have been correlated with virus infection (Robertson and Smith, 1931).

Studies by various workers (Bolas and Bewley, 1930; Iyengar, 1928; and Rouzinoff, 1930) seem to suggest that normal plants are less acidic than virus-infected plants. Tannins have been reported to be correlated with virus infection (Murza, 1948).

To determine if the tannin contents and the pH values of the plant sap of the leaves of mosaic-resistant and susceptible species of abacá are related to the presence or absence of a resistance to abacá mosaic, this study was conducted from April, 1954, to January, 1955. Color tests for the presence of tannins in abacá and related species were also investigated.

MATERIALS AND METHODS

The materials studied were normal and mosaicked seedlings of susceptible species (abacá and canna) and seedlings of resistant spe-

[1] Central Experiment Station Contribution No. 1915. Thesis presented by the senior author for graduation with the degree of Bachelor of Science in Agriculture from the College of Agriculture, March, 1955. Prepared in the Department of Agricultural Chemistry under the direction of the junior author.

cies (pacol, abacá, pacol-abacá hybrids, abacá-canton hybrids and *Musa lolodensis*), all ranging in age from six to eighteen months. The mosaic-infected plants were supplied by the Department of Plant Pathology. For each species, five samples from each of five plants were taken for analysis.

Aqueous extracts of whole leaves of each plant were prepared by comminuting 10 grams (fresh weight) of the leaves with 50 ml. of distilled water in the Waring blendor. The blended sample was filtered through nonabsorbent cotton and made up to 100 ml. Distilled water was used in washing the precipitate. The pH of the filtrate was then determined with the Beckman pH meter. Five determinations were made of aliquots of the filtrate.

The diagnostic test of Lindner *et al.* (1951) for viruses of fruit trees was followed and later modified. Preliminary experiments with leaf disks cut out with a cork borer one centimeter in diameter gave colored solution which could be visually differentiated. Twenty disks from different parts of the leaves were heated with 5 ml. of the reagent for 10 minutes and then diluted with 5 ml. of water while being cooled for 10 minutes. The absorption characteristics of the cooled mixture was determined with the Coleman spectrophotometer. In another experiment, the chlorophyll of the leaf disks was removed with a solution of ethyl alcohol, water, and formaldehyde before treatment with the reagent. Based on the absorption obtained, subsequent readings at 10 mu-intervals were made at 400 to 500 mu. Later, 5-gram amounts of the leaves were boiled for 20 minutes in 10 ml. of water, and the aqueous extracts were then treated with the alkaline reagent. The effects of age and position of leaf sample on the spectrophotometric readings were also studied.

In a preliminary experiment, the abacá plant sap taken up in filter paper strips gave a brown color with potassium ferricyanide after exposure to ammonia vapor. In previous experiments in the Department of Agricultural Chemistry consistent spectrophotometric readings were obtained at 430 to 450 mu. of low concentrations of tannic acid with 2 ml. of 0.1 N $K_3Fe(CN)_6$ and 2 drops of 1.0 N NaOH. The same proportion was used in the subsequent analysis of the plant samples.

Five-gram leaf samples were chopped and then boiled for 20 minutes in 30 ml. of water to extract the tannins. The resulting mixture was cooled, filtered into a 50-ml. volumetric flask, and made

up to the flask's volume with distilled water. The reagents were added to 10 ml. of aliquots, and 10 mu-interval readings were immediately taken in the Coleman spectrophotometer at 400 to 500 mu.

The diagnostic test applied by Hirata (1950) on virus-infected potato tubers is based on the length of time required for the color of starch-iodine solution plus potato juice to fade. Preliminary experiments with phenol and other hydroxy aromatic compounds, such as resorcinol, orcinol, pyrogallol and tannic acid, showed that these compounds can decolorize the starch-iodine reagent. In this work, the same proportion of the reagents used by Hirata (0.5 ml. of 1.5% soluble starch and 1-3 ml. of 2% iodine solution in 30% ethyl alcohol in water) was tried with the acqueous extracts of the leaves of the different plants. The aqueous extracts were prepared as in the ferricyanide test.

Kursanov and Zaprometov (1949) have developed a quantitative method for determining neighboring (1, 2, 3) and ortho-hydroxy groups in polyphenols and tannins by using ferrous salts which give blue to violet color in the presence of tartrate. Ferric chloride also gives the same color with these polyphenols. These salts were used as color tests in this study with boiled aqueous extracts and juices from the stems and petioles of the different plants. The reagent consisted of equal volumes of 0.1 per cent $FeSO_4$ and 1 per cent Rochelle salt. Five-milliliter aliquots of 50 ml. aqueous solution of 5 g. leaves were treated with 2 ml. of the reagent and 2 ml. of the 0.1N ferric chloride for the other test. Spot tests on filter paper were also made. After the sap from the stems and the petioles had been squeezed on strips of filter paper, the spots were dipped in the reagents, and the colors obtained were then visually compared.

RESULTS AND DISCUSSION

pH of the plant sap. The pH values of the aqueous extracts of the leaves of the mosaicked abacá plants ranged from 5.7 to 6.2; those of mosaicked canna, 6.1 to 6.3; those of mosaic-resistant plants (canton, pacol, the hybrids, and *Musa lolodensis*), 5.9 to 6.4; and those of healthy abacá and canna, 6.4 to 6.7 (table 1). The 5.7 to 6.7 range of pH found for all the plants was much higher than the isoelectric point of some known viruses (tobacco mosaic virus, pH 3.4; potato virus and tomato bushy stunt virus, pH 4.5). Takahashi (1949) reported that the infectivity of different tobacco-mosaic virus preparations was lower at pH 5.6 than at pH 7.0. The linear aggregation of the virus particles seemed to occur at lower pH. Al-

though the differences in pH between the different plants were not conclusive enough to be correlated with virus resistance, the results apparently indicate that mosaicked leaves of abacá and canna have lower pH than normal leaves. More determinations which take into account the known factors that affect the pH of the plant sap, such as fertilization and age of the plants and leaves, but which were disregarded in this study must be made before it can be proved that virus infection lowers the pH of the leaves.

TABLE 1.—*pH of the aqueous extracts of the leaves of abacá and related species*

PLANT	REPLICATION					
	I	II	III	IV	V	Range
Healthy abacá	6.4	6.5	6.6	6.6	6.5	6.4-6.6
Mosaicked abacá	5.9	5.9	6.2	6.0	5.7	5.7-6.2
Healthy canna	6.5	6.4	6.7	6.5	6.7	6.4-6.7
Mosaicked canna	6.3	6.1	6.1	6.1	6.1	6.1-6.3
Pacol	6.3	6.1	6.2	6.1	6.0	6.0-6.3
Pacol × abacá	6.2	6.1	6.3	6.0	6.2	6.0-6.3
Canton	6.4	6.0	6.4	6.4	6.0	6.0-6.4
Canton × abacá	6.3	6.1	6.4	6.6	6.3	6.1-6.6
Musa lolodensis	5.9	5.9	5.9	6.0	6.0	5.9-6.0

If tannin production is a defense mechanism for virus infection, as Lindner *et al.* (1951) have postulated, and since Hirth (1951) has found that some tannin substances inhibit tobacco mosaic virus, then it is probable that abacá and its relatives are resistant to certain viruses if they have unusually high tannin content. This assumption was the basis of the subsequent color tests for the presence of tannins in abacá and related species.

Lindner's test. The absorption characteristics of the leaves of the different plants with Lindner's reagent are shown in figure 1. Most of the plants showed maximum absorption with 410 to 460 mu. However, marked differences in the percentage of transmission of diseased and healthy abacá plants were obtained from 460 to 500 mu. Thus, subsequent comparisons in percentage of transmission were made at 460 to 500 mu.

Among the virus-resistant plants, *Musa lolodensis* gave consistently lower readings than the others (table 2). Pacol, canton, and their hybrids with abacá showed no marked differences when compared with abacá and canna which are susceptible to the mosaic virus.

Diseased abacá plants appeared to exhibit lower readings than the normal plants, but the reverse was true with canna (fig. 1a).

TABLE 2.—*Spectrophotometric readings of the abacá leaves and related species with Lindner's reagent*

PLANT	PERCENTAGE OF TRANSMISSION AT 460μ				
	I [a]	II [b]	III [b]	IV [b]	V [b]
Healthy abacá	52.0	63.9	73.1	58.0	67.4
Mosaicked abacá	41.2	50.3	37.3	27.2	42.6
Healthy canna	53.0	76.0	82.4	73.2	77.3
Mosaicked canna	56.2	78.0	77.3	76.4	82.8
Pacol	52.2	81.3	83.6	72.3	77.6
Pacol × abacá	53.2	77.8	71.6	66.4	65.0
Canton	43.3	73.1	61.7	73.8	70.2
Canton × abacá	59.6	86.5	82.3	73.8	71.6
Musa lolodensis	41.1	37.9	42.3	38.9	48.7

[a] Leaf disks were used (figs. 1a and 1b).
[b] Five-gram samples boiled with H_2O and aliquots were analyzed.

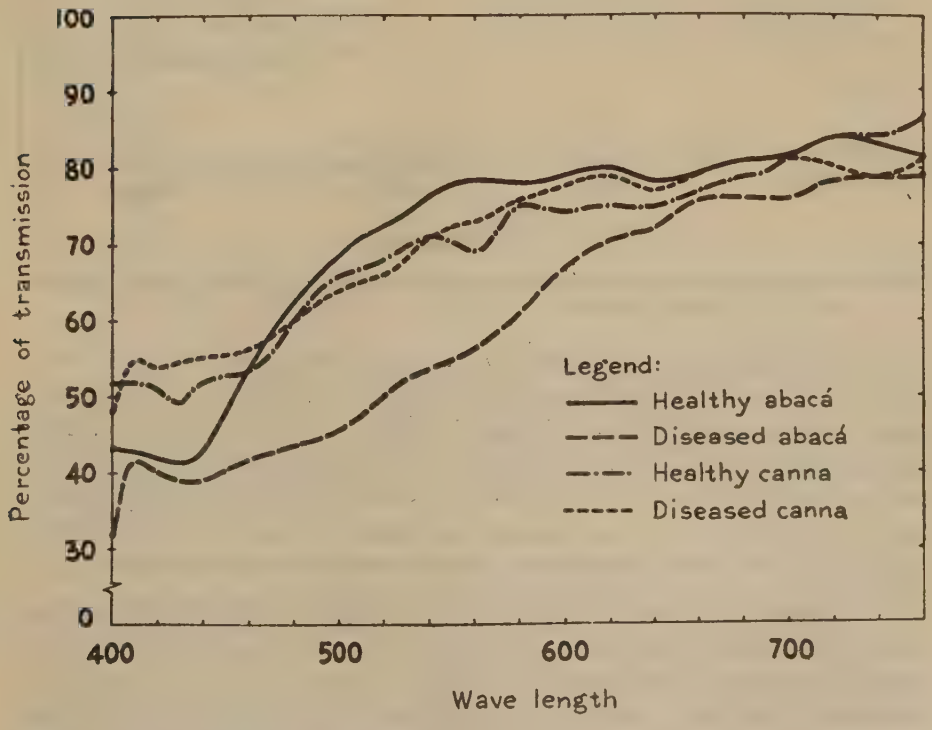

Fig. 1a.—Absorption characteristics of the colored compounds of abacá and canna with Lindner's reagent.

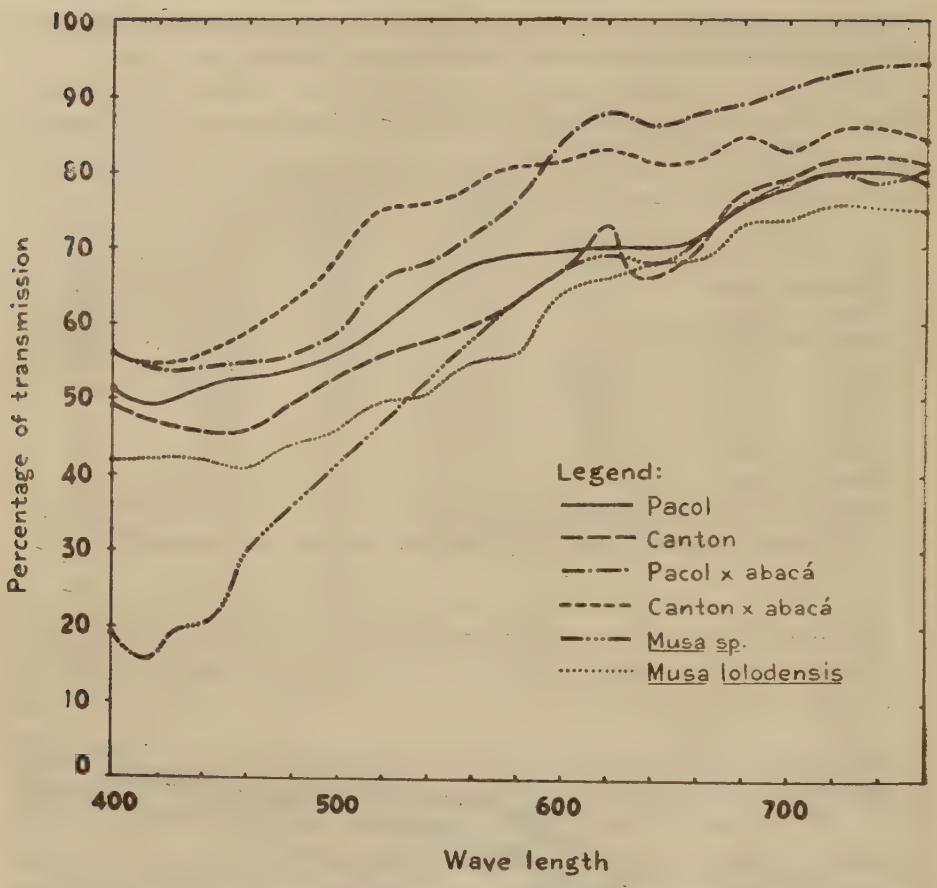

Fig. 1b.—Absorption characteristics of pacol, canton, hybrids and *Musa lolodensis* with Lindner's reagent.

If the tannins or polyphenols do cause such color changes, further work should be done to compare the tannin content of healthy abacá plants with that of diseased plants, with emphasis on the polyphenol system involved and on the factors other than virus infection that tend to affect the level of tannins in abacá. In this connection, preliminary experiments were made to determine the applicability of the tannins present in healthy and diseased abacá plants.

In *Musa lolodensis*, extraction with aqueous alcohol to remove chlorophyll before adding the reagent gave curves without any noticeable absorption maximum (fig. 2). Undoubtedly, the substances involved in the color reaction were also extracted together with plant pigments by the solvents. The laminae of pacol and canton leaves

gave higher readings than the midribs (table 3.) The readings were also affected to some extent by the age of the leaves. This is a factor that should be considered in future studies using the same test.

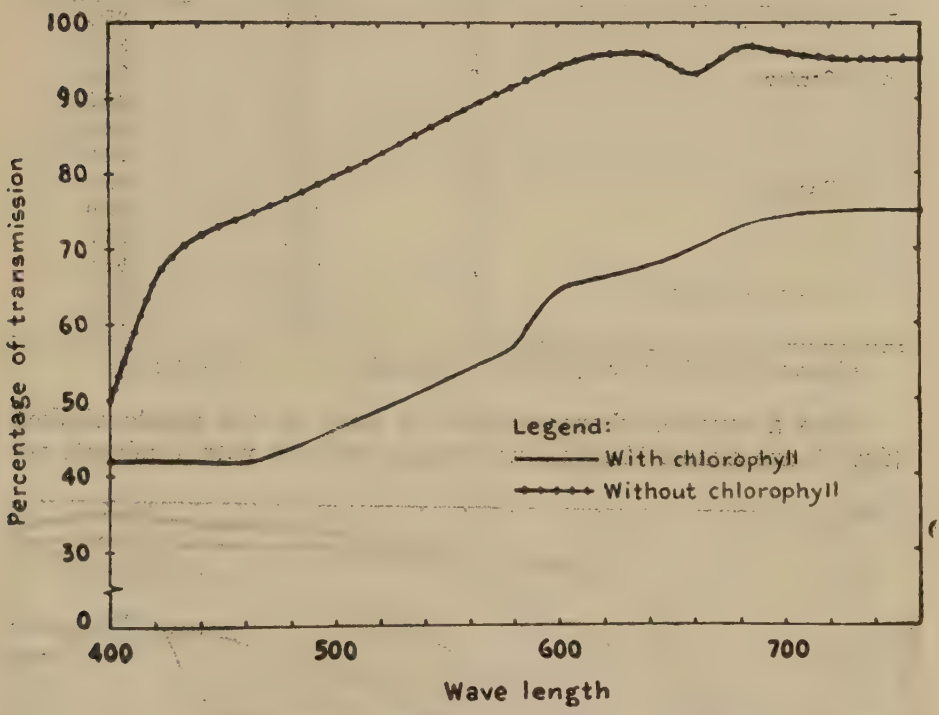

Fig. 2.—Effect of aqueous alcohol on the absorption characteristic of *Musa lolodensis* with Lindner's reagent.

Alkaline potassium ferricyanide. The reaction of tannins to potassium ferricyanide in alkaline solution was tried because some plant pigments which might have been extracted and converted to other substances might have interfered with the spectrophotometric determination.

Preliminary experiments with tannic acid and the reagents in the Department of Agricultural Chemistry showed a shift in the absorption (420-460 mu.) towards the longer wave length as a result of the reaction. The nature of the reaction to the concentration of tannic acid did not follow Beer's law. However, in concentrations ranging from 1.14 to 24 mg., the optical density was directly proportional to the concentration.

TABLE 3.—*Effect of age and part of leaves on the spectrophotometric readings of the leaves with Lindner's reagent*

PLANT	POSITION OF SAMPLE ON LEAF [a]	PERCENTAGE OF TRANSMISSION AT 460μ	
		Laminae	Petiole and midrib
Canton	1	49.5	85.0
	2	52.7	80.0
	3	61.7	89.5
	4	73.8	88.9
Pacol	1	77.2	92.0
	2	83.4	92.0
	3	83.1	95.4
	4	82.4	95.0
Pacol × abacá	1	71.6	88.2
	2	66.4	85.6
	3	65.0	84.5
	4	84.0	92.2

[a] Leaves came from one plant; 1 = the oldest; 4 = the youngest.

The absorption characteristics of some of the plants studied (fig. 3) are almost identical with those obtained with Lindner's re-

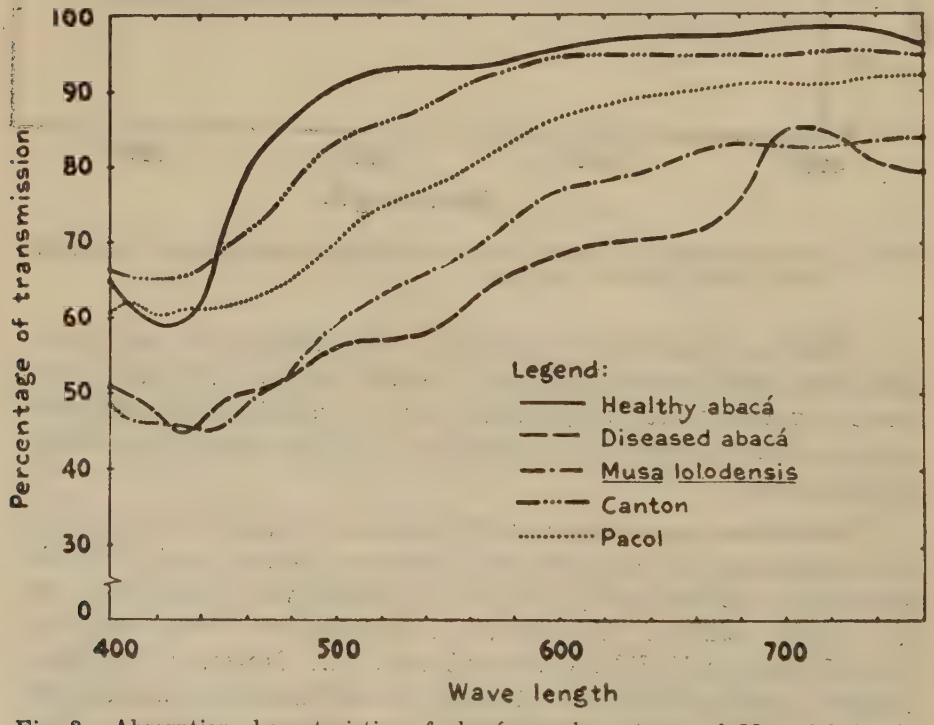

Fig. 3.—Absorption characteristics of abacá, pacol, canton, and *Musa lolodensis* with alkaline $K_3Fe(CN)_6$.

agent (fig. 1). Likewise, no marked difference in the readings of percentage of transmission were found among healthy abacá, pacol, and canton, whereas mosaicked abacá and *Musa lolodensis* gave lower readings than the former group at 460 mu. (table 4). Because of the similarity in results between the two tests, the ferricyanide test was not extended to canna and the abacá hybrids. However, the sap of all the plants drained on filter paper strips gave identical brown coloration with potassium ferricyanide after exposure to ammonia vapor. Because of the lesser amount of alkali used, this test may be better than Lindner's. Polyphenols are readily oxidized in hot alkaline solutions.

TABLE 4.—*Spectrophotometric readings of the abacá leaves and related species with alkaline* $K_3Fe(CN)_6$

PLANT	PERCENTAGE OF TRANSMISSION AT 460μ				
	I [a]	II	III	IV	V
Healthy abacá	80.0	63.2	76.3	73.8	63.5
Mosaicked abacá	49.0	37.2	39.0	33.4	42.8
Pacol	62.0	57.1	66.3	69.2	73.1
Canton	70.5	72.9	68.9	76.3	70.2
Musa lolodensis	48.5	35.9	38.2	42.1	39.8

[a] See figure 3.

Starch-iodine test. All the plants, except those of canna (healthy and diseased), caused immediate fading of the blue color of the starch-iodine solution. In canna, the fading of the color was not so marked as in abacá and related species. Determinations of the time of discoloration by the dilution of the extract or the reagent could not be made because the color of the extracts interfered with the visual observation. Probably, spectrophotometric determination of the blue color can be made if the reaction is stopped after a certain length of time by the addition of some inhibitors. The addition of acid or base to stop the reaction gave unsatisfactory results. Thus, this test has poor diagnostic value in the determination of mosaic virus infection if polyphenols are involved. Phenol and other hydroxy aromatic compounds (resorcinol, orcinol, pyrogallol, and tannic acid) decolorize starch-iodine solution. Perhaps the similarity in the reactions of polyphenols and aqueous extracts of the leaves of the *Musa* species to starch-iodine, potassium ferricyanide, and Lindner's reagent shows the presence of polyphenols in the leaves.

Tests with iron salts. These tests with ferric chlorides and ferrous sulfate were tried to minimize variations due to differences in the phenolic system of the plants; for, according to Kursanov and Zaprometov (1949), ferrous salts in the presence of tartrate give blue to violet color with vicinal (1, 2, 3) and ortho (1, 2) hydroxy phenols. Except with *Musa lolodensis* no detectable blue color was obtained when aliquots of the boiled aqueous extracts of the leaves and stem were treated with ferric chloride and ferrous sulfate. However, the plant sap from the stems, petioles, and laminae of all the plants, except canna (healthy and diseased), gave a positive test when treated with these reagents on filter paper. This difference between the boiled sample and the fresh sap is probably due to dilution and, to some extent, to the oxidation of the polyphenols during the hot extraction. Ferric chloride gave the same color reaction as ferrous sulfate.

The presence of polyphenols or tannins in the *Musa* species has been established by several color tests, namely, alkaline ferricyanide, starch-iodine solution, ferrous sulfate, and ferric chloride. Although there were some indications that more tannins were present in mosaicked abacá than in the normal plants, tannin formation is perhaps not directly involved at all with mosaic infection because diseased and healthy plants of canna did not exhibit any polyphenol systems. If tannins were a factor at all perhaps the level of tannins in *Musa* species or the characteristic nature of the polyphenol systems has some relation to the resistance of *Musa lolodensis,* pacol, canton x abacá and abacá x canton to abacá mosaic.

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ERRATUM

In volume XL, No. 2, July, 1956 number of *The Philippine Agriculturist*, the article

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